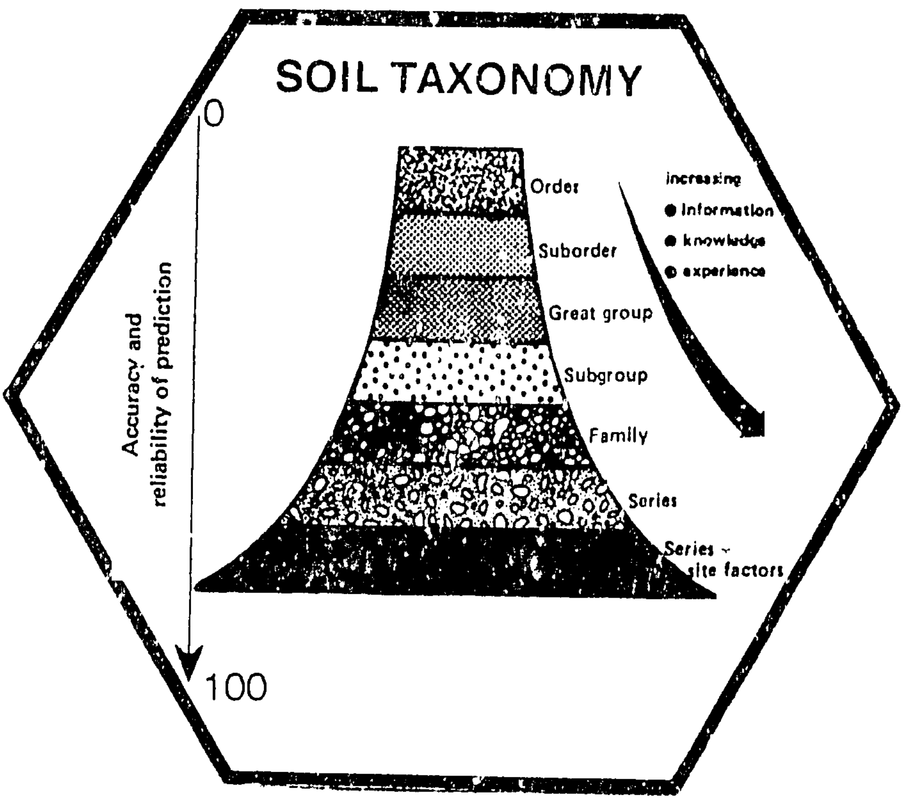
XIV INTERNATIONAL FORUM ON SOIL TAXONOMY AND AGROTECHNOLOGY TRANSFER

Technical Papers



PHILIPPINES

June 16-28, 1986

XIV International Forum on Soil Taxonomy and Agrotechnology Transfer

June 16 - 28, 1986

P H I L I P P I N E S

PROGRAM OF ACTIVITIES

15 June (Sunday)

	Participants arrive at Iloilo City	
1600	Registration	
1900	Getting-to-know-you reception	S M S S

16 June (Monday)

	OPENING CEREMONIES	
0830	Pambansang Awit	
0835	Welcome Remarks	Emigdio Fabella Director MAF-Region VI
0850	Short Messages	
	S M S S	H. Eswaran Program Coordinator S M S S
	B S	G.N. Alcasid Director Bureau of Soils
	ARO - MAF	C. Fernandez Assistant Director M A F
	P C A R R D	A. Maglinao Director FRSRD, PCARRD
0930	B R E A K	

Technical Session I

1115	Soil Taxonomy, a technical language of soil science (a movie)	H. Eswaran Program Coordinator SMSS
1145	Purpose of Forum	H. Eswaran
1200	L U N C H	

Technical Session II

1315	Historical development of Soil Taxonomy	J. Kimble Soil Scientist SMSS - SCS
1400	Principles of soil classification	H. Eswaran
1445	Structure of soil taxonomy	H. Eswaran
1530	Diagnostic surface horizons	M. Recel
1615	B R E A K	
1630	Diagnostic subsurface horizons: cambic, argillic, kandic, spodic, oxic, others	J. Kimble

17 June (Tuesday)

Technical Session III

0800	Diagnostic properties	M. Recel
0845	Soil moisture and temperature regimes	J. Kimble
0930	Soil Laboratory Analysis for Soil Classification	M. Recel
1015	B R E A K	
1030	Entisols and Inceptisols	M. Recel
1115	Vertisols	H. Eswaran
1200	Alfisols and Ultisols	S. Paramananthan Universiti Pertanian Malaysia
1245	L U N C H	

1400	Mollisols	L. Moncharoen Land Development Department Thailand
1445	Oxisols	H. Eswaran
1530	Histosols	J. Kimble
1615	B R E A K	
1630	How to classify	H. Eswaran and M. Recel
1715	Charge characteristics of soils	H. Eswaran
1800	Mineralogy of soils	G. O. San Valentin U P L B

18 June (Wednesday)

Field Trip I

0730

Pedon 1 Sara Series
Pedon 2 Barotac Series
Pedon 3 Alimodian Series

19 June (Thursday)

Field Trip II

0630

Leave by boat to Bacolod

Pedon 4 Guimbalaon Series
Pedon 5 Bago Series

Overnight in Bacolod City

20 June (Friday)

Field Trip III

0800

Pedon 6 Tupi Series
Pedon 7 Silay Series
Pedon 8 Isabela Series

Overnight in San Carlos City

21 June (Saturday)

	Field Trip IV	
0500	Leave San Carlos	
0800	Arrive Toledo	
0900	Skyview (SNACK)	
1100	Pedon 9 Mandaue Series (Compostela)	
1300	L U N C H	
1430	Pedon 10 Mandaue Series (Talisay)	
1600	Skyview (REST)	
1830	D I N N E R	
1930	Review of profiles studied	J. Kimble
2015	Report of follow up exercise of VII Forum	H. Eswaran and M. Recel
2200	Leave Cebu	

22 June (Sunday)

0400	Arrive Ormoc	
0530	Arrive Baybay	
0600	B R E A K F A S T	
0700	R E S T	
1200	L U N C H	
	Technical Session III	
1300	Physical properties of soil	E. Paningbatan U P L B
1345	Soil property interrelationship	H. Eswaran
1430	Micromorphology of soils	H. Eswaran
1515	Soil fertility management implications of Soil Taxonomy	B. Cagauan
1600	B R E A K	

1615	The minimum data set for crop modelling for agrotechnology transfer	B. Cagauan
1700	Principles of soil survey interpretation	J. Kimble
1745	Exercises in soil survey interpretation	J. Kimble
1845	A D J O U R N	
1900	D I N N E R	

23 June (Monday)

Field Trip V

0700 Pedon 11 Maasin Series
Pedon 12 Series Not Defined (Abuyog Site)
Pedon 13 Dolongan Series
Pedon 14 Catbalogan Series

2130 Leave Tacloban for Legazpi City

24 June (Tuesday)

Field Trip VI

0730 Pedon 15 Sorsogon Series (INSFER Site)
Pedon 16 Castilla Series (Benchmark site-Del Rosario Farms)

Overnight in Legazpi City

25 June (Wednesday)

Field Trip VII

0830 Pedon 17 Isarog Series (Benchmark Site-PUC)

1800 Leave Legazpi for Manila

1830 Arrive Los Baños

26 June (Thursday)

0600 B R E A K F A S T

0700 R E S T

1200 L U N C H

1300	Soil Survey interpretation of local data	A. Alcantara
1400	Preparation of Participant's Accomplishment Report	

27 June (Friday)

	Technical Session IV	
0800	Agronomy of coconut	S. Magat Manager Agricultural Research Department P C A
0845	Agronomy of cacao	B. Azucena Manager Soils Department T R R C
1000	B R E A K	
1015	Agronomy of soybean	L. Ragus Supervising Science Research Specialist CRD - PCARRD
1100	Agronomy of rubber	S. Nalasan F E L D A Malaysia
1145	Agronomy of oil palm	Hew Choy Kean Consultant in Agriculture and Land Development
1230	L U N C H	
1400	Agronomy of sugarcane	V. Dosado Head Agronomy Department P H I L S U C O M
1445	Agronomy of cassava	F. Villamayor P R C T R C
1530	Farming systems research in the Philippines	A. Gomez Consultant RRDP - MAF

1615	B R E A K	
1630	Research priorities in agriculture in the Philippines and the ASEAN region in general	R.V. Valmayor Executive Director PCARRD
1715	Discussion on priorities of soil research in the ASEAN region	
1830	A D J O U R N	

28 June (Saturday)

Technical Session V

0800	Agrotechnology transfer based on Soil Taxonomy	F.H. Beinroth Co-Principal Investigator I B S N A T
0845	A systems-based approach to agrotechnology transfer	F.H. Beinroth
0930	Soil suitability and management implications of Soil Taxonomy with special reference to tree crop cultivation	S. Paramananthan
1015	B R E A K	
1030	National and regional projects of agrotechnology transfer in the ASEAN region	C. Escaño
1115	Demonstration of crop simulation models and acid soil expert system	B. Cagauan
1200	Exercises with IBSNAT software	
1245	L U N C H	
1400	Report on soil survey and classification in the Philippines	A. Dayot Chief, Soil Survey Division B S
1445	Report of soil survey and classification in Indonesia	M. Soekardi Center for Soil Research Indonesia

1530	Report on soil survey and classification in Malaysia	S. Paramananthan
1615	B R E A K	
1630	Report of soil survey and classification in Thailand	L. Moncharoen
1830	CLOSING CEREMONIES	
1930	D I N N E R	

T E C H N I C A L   P A P E R

		SPEAKER
1.	Historical development of Soil Taxonomy	R. Yeck
2.	Diagnostic surface horizons	M. Recel
3.	Diagnostic properties	M. Recel
4.	Soil moisture and temperature regimes	J. Kimble
5.	Soil laboratory analysis for soil classification	M. Recel
6.	Entisols and Inceptisols	M. Recel
7.	Alfisols and Ultisols	S. Paramananthan
8.	Mollisols	L. Moncharoen
9.	Histosols	J. Kimble
10.	Mineralogy of soils	G.O. San Valentin
11.	Physical properties of soil	E. Paningbatan
12.	Soil fertility management implications of Soil Taxonomy	B. Cagauan
13.	Agronomy of coconut	S. Magat
14.	Agronomy of cacao	D. Azucena
15.	Agronomy of soybean	L. Ragus
16.	Agronomy of oil palm	Hew Choy Kean
17.	Agronomy of sugarcane	V. Dosado
18.	Agronomy of cassava	F. Villamayor
19.	Agrotechnology transfer based on Soil Taxonomy	F. Beinroth
20.	A systems-based approach to agrotechnology transfer transfer	F. Beinroth
21.	Soil sustability and management implications of Soil Taxonomy with special reference to tree crop cultivation	S. Paramananthan

HISTORICAL DEVELOPMENT OF SOIL TAXONOMY

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I. INTRODUCTION:

A year or two before Milton Whitney initiated the U.S. Soil Survey in 1899, he stated (Brasfield, 1984), "we need a soil survey in order to be able to transfer experience, from research or the use of soils, from the fields or areas where we have experience, to other soils or areas where it that is applicable". That process described by Whitney before the turn of the century is the very essence of what we now term Agrotechnology Transfer. Since soil survey has long been recognized as an essential ingredient of Agrotechnology Transfer, it is appropriate and necessary that we study Soil Taxonomy, along with Agrotechnology Transfer in this forum.

We may pose the question of why we should spend our time considering the past by discussing the history of Soil Taxonomy. I think the answer is analogous to why we are interested in our own historical roots. To a large degree, each of us is influenced by our heritage, including the events and circumstances that influenced the decisions of our ancestors. Also, by knowing some of the traits of our parents, grandparents, and perhaps even great grandparents, and the decisions they made in given situations, we may more fully understand who we are. And finally, a better understanding of ourselves may inspire our plans for the future.

In a similar way, if we think about the roots from which Soil Taxonomy sprang, it will give us a better insight to its philosophical foundations, the type of criteria that govern classifications, and even its unique language. From that knowledge, we may also be able to help shape the Soil Taxonomy of the future.

To give us a bit an overview of our topic, let's consider some significant milestones in the development of Soil Taxonomy. They are shown in Table 1.

[1/] Paper presented at the XIV International Forum on Soil Taxonomy and Agrotechnology Transfer, Philippines.

Table 1. Historical Development of Soil Taxonomy - Milestones.

187?	-	Development of the Concept of soil forming processes by Dokuchaiev
1899	-	Beginning of Soil Survey in the United States
1912	-	G.N. Coffey published USDA Bureau of Soils Bulletin 85, A Study of the Soils of the United States
1914	-	Russian Concepts published in German by Glinka
1921	-	Translation of Glinka's book into English by Marbut
1938	-	U.S. Classification published - Soils and Men
1951	-	Organized effort to develop new U.S. classification initiated. Soil Survey Manual published.
1960	-	New U.S. scheme presented to the 7th International Congress of Soil Science, Madison, Wisconsin. 7th Approximation published.
1965	-	New U.S. classification scheme adopted for use in the U.S.
1975	-	<u>Soil Taxonomy</u> published

Now that we have looked at some markers for our historical journey, let's take the trip again, now spending considerably more time at some of the milestones than at others.

II. SOIL CLASSIFICATION IN THE U.S. PRIOR TO INCEPTION OF THE NEW SYSTEM:

In the U.S., the beginning of the soil survey preceded the use of a national soil classification scheme. Some of the concepts that eventually became cornerstones of the U.S. classification system, however, had already been formulated by Dokuchaiev, as indicated in Table 1.

As pointed pointed out by Ableiter (1949), George N. Coffey of the U.S. Bureau of Soils was influenced by the ideas of Dokuchaieve and published "A Study of the Soils of the United States" (Coffey, 1912), outlining a classification system that considered soil as an independent, natural body. His classification was based on soil genesis, and it recognized inherent differences in the soil itself. The prevailing view in the U.S., however, was to treat soils from a geological point of view, and Coffey's ideas were not accepted. Smith (1983) states that Coffey's ideas were too advanced for the time. A few more U.S. pedologists became familiar with the Russian pedological concepts because of Glinka's German translation that arrived in the United States around 1914. It was not, however, until Dr. Charles Marbut, head of the U.S. Soil Survey, translated the work into

English, about 1921, that it became generally familiar to U.S. pedologists and accepted by them. The fundamental thesis of Dokuchaiev was that soil was a distinct, independent, natural-historical body (Joffe, 1949). From this concept, he felt that the factors of soil formation, in any climatic zone over a geographic region, determine the type of soil as manifested in the profile. Dokuchaiev said "If we know the factors of soil formation, we can predict what the soil would be like". He listed the factors as parent material, plant and animal organisms, climate, age of the land, and topography. Later, when we begin to study Soil Taxonomy, we will see that these concepts are still central to our present understanding of pedology.

In 1928, Marbut presented a soil classification scheme based on the above Russian pedological concepts. He later published a more detailed version of his scheme in the Atlas of American Agriculture in 1935. He introduced the concept of Pedalfers, soils distinguished by accumulations of aluminum (Al), and iron (Fe), and Pedocals, distinguished by accurmulation of calcium carbonate, ($CaCO_3$) at the highest classification category. Although Marbut's scheme proved not to be inclusive of all soils, if reflected our understanding of soils at that time and was the first accepted step in the U.S. for formalizing a soil classification scheme. In 1937, in an attempt to develop a more complete classification scheme, Secretary of Agriculture Henry Wallace, asked Dr. Charles Kellogg, head of the U.S. Soil Survey, to develop a year book of agriculture reflecting all that was known about soils, including weaknesses of our knowledge, at that time. Thus, the 1938 USDA Yearbook of Agriculture, Soils and Men, was published, including a newer scheme of soil classification. At the highest category (Order), this scheme incorporated the Russian concepts of Zonal soils (those fully reflecting soil forming factors), Intrazonal soils (those reflecting dominance of local factors), and Azonal soils (soils without genetic horizons). Zonal soils were still subdivided into Pedalfers and Pedocals. Suborders grouped soils by climate and vegetation, but the third highest category, great soil groups, seemdd to have the most appeal in this sytem. Although this was an improvement over Marbut's first scheme, it still did not accommodate all of the soils of the United States. World War II interrupted continued work on soil classification. After the war, Dr. Kellogg assigned committees to study the Great Soil Groups of the '38 system (they included groups with names such as Brown Podzolics, Chernozems, etc.). In 1949, an updated version of the 1938 classification scheme was published (Thorp and Smith, 1949) that no longer included grouping by Pedalfers and Pedocals and added more great soil groups. This scheme, although more inclusive, was still not completely satisfactory. In 1950, since it was apparent there were too many shortcomings of the U.S. system and other systems known to Dr. Kellogg, the decision was made to develop a new system of soil classification that would accommodate all of the U.S. soils and hopefully others as well.

It is of interest to us to know those features that Dr. Kellogg listed as shortcomings of previous systems. Because correction of those problems would certainly be addressed by the architects of the new classification scheme, he listed them as follows:

1. Concepts and definitions were based on factors outside of the soil itself and not on soil properties.
2. Zonal, Intrazonal, and Azonal groupings were ambiguous in terms of soil properties.
3. Many soils were defined on the basis of virgin conditions.
4. Lower system categories were defined on too few properties (limiting interpretation potential).
5. Soil color was over-emphasized.
6. Nomenclature for higher categories (great soil groups) evolve from several languages (mixtures of nouns and adjectives) making it difficult to name intergrades.

In support of the effort to develop a new comprehensive soil classification system, activities of the soil survey laboratories were directed toward gathering data for the new system. Also, in 1951, a Soil Survey Manual was published which established standard methods of describing soils. This was especially important because it provided a uniform system of documenting field data that would be a necessary part of the new system.

Dr. Guy Smith was assigned by Dr. Kellogg to head up the efforts for development of the new system. Dr. Smith's training and experience particularly suited him for this task and the new scheme was to reflect his scientific philosophy. He had studied under Jenny (author of a book attempting to quantify the soil forming factors). Dr. Jenny introduced him to the writings of P.W. Brinkman, a strong advocate of quantitative methods in science. Dr. Smith insisted, therefore, that criteria proposed for the new system be measurable, and he carefully screened each proposal based on its logic and documented evidence of validity. Dr. Smith gained a reputation for his skill in sifting through divergent and strongly held views as he produced a series of "approximations" of the new system for review and testing. He never abandoned a rigorous and scientific approach for the system and also insisted that rather than just an academic exercise, that it be useful. With this background, we are ready to consider, in some depth, the concepts on which the new classification system was based.

III. CONCEPTION AND EVOLUTION OF THE "NEW CLASSIFICATION SYSTEM":

The concepts of Dokuchaiev (that soils are natural-historic bodies that reflect the influence of soil forming factors) continued as an unbroken thread through the early U.S. classification schemes and continues as a major part of the philosophy of the new classification, but with some shift in emphasis. The factors of soil formation proposed in Russia have stood the test of time. The concept of soil as a three-dimensional natural body remains as an underlying concept in <u>Soil Taxonomy</u>, but the logic of that concept has been questioned in recent years (Holmgren, 1985). A lesson learned from the early U.S. schemes, however, was that soil genesis as a direct and primary for soil classification is too subjective. If we were to try to predict where all soils occur based on their perceived genesis, and classify them <u>a priori</u>, the accuracy of our classifications would be limited to our understanding of soil genesis. That understanding is seldom complete, and thus may be interpreted with divergent conclusions among researchers. Another shortcoming of the early schemes was the difficulty of assigning soils to classifications from one level in the classification scheme to another. This experience from the earlier classifications, including the shortcomings listed earlier by Dr. Kellogg, played a major role in determining the objectives, assumptions, and operating guidelines for developing the new classification system.

Smith (1963) discussed the objectives, and basic assumptions of the new classification system. The assumptions follow:

1. Soil is the result of the interaction of climate, relief, and living organisms, including man, acting over time on parent material. Wherever these factors have been the same, the soil is the same (first stated by Dokuchaiev).
2. Wherever the soils are the same, the responses that depend upon soil properties are the same.

He further pointed out that the intent was to develop a classification system that was both natural and comprehensive.

Smith (1963) quotes Cain as saying that a natural classification system is a grouping of things "that belong together", although that is rarely a unanimous decision. Cline (1949) further notes that in a natural system, one classifies in such a way that the name of each class will bring to mind many characteristics and will fix each group mentally in relation to all others. He says the objective is to show relationships in the greatest number and most important properties. The lowest category is a prerequisite to all other groupings. The individual is the object of classification at the lowest level in a natural scheme. Therefore, having considered soils as natural bodies, defining a soil individual (in this case the polypedon, defined later) was considered essential in this natural soil classification scheme.

A comprehensive system, explained by Smith (1963), is one designed to permit inclusion of all soils. He further noted that the system devised would be incomplete as written, but that it would provide for accommodation of additional soils as they became known. He further noted that a multicategoric system was needed for two reasons. First, the human mind is limited to the information it can comprehend at one time, and with the subdivisions of such a multicategoric system, only those subdivisions of interest need be comprehended at one time without considering the entire system. A second reason is the opportunity to consider soils at different levels of generalization.

A fundamental feature of the system was to have the taxa defined in terms of observable or measurable properties. The taxa concepts are in part genetic, but differentiating criteria are operational. Thus, the system is genetically based but does not use soil genesis directly in the definitions of the classes. Genesis, therefore, lies behind the definitions and is one step removed from them. The rationale for defining taxa in terms of soil properties follow:

1. We are trying to classify soils, not soil-forming factors or processes.
2. Definitions in terms of soil properties focus attention on the soil itself rather than on related sciences (geology, climatology, etc.).
3. Soils of unknown genesis cannot be classified if definitions are written in terms of soil genesis.
4. A classification is needed that can be applied with reasonable uniformity by large numbers of soil scientists.

For uniform application of the definitions, they must be defined in such a manner that each scientist applying the definitions will apply them in a similar manner. Thus, procedures for recording observations and methods of making measurements for applying the criteria are defined. These are termed operational definitions. For example, the pH at which we determine cation exchange capacity (CEC) determines our result. Thus, we must specify the method of determining CEC to be used for a given taxonomic criteria. Clearly, the concept of operational definitions is very important to uniform application of definitions.

It is useful for us to understand the basis on which distinguishing diagnostic properties were chosen. The following properties were listed by Dr. Smith:

1. Only those properties that now exist or can be demonstrated should be used.
2. Properties that are the result of soil genesis for that influence soil genesis should be used for the definition of taxa (this relates to categories above the family level).
3. Properties selected should be measurable.

Since the nomenclature of Soil Taxonomy is unique, it is of interest to know the principles used in coining the names. They are as follows:

1. Formative elements were to come from the classical languages insofar as possible. The names must be mnemonic and connote some of the properties. They should fit readily into as many modern languages as possible and be distinctive.
2. The name should indicate the place of a taxon in the system. From the name, one should be able to recognize both the category of the taxon and the taxa in any of the higher categories to which it belongs.
3. The names should be as short as possible. This is critical in the higher categories if the names of taxa in lower categories are to be manageable in speech.
4. The names should be as euphonic as possible.
5. Existing terms were to be avoided.

Prior to considering some points of logic of the classification system, it is worthwhile to reflect on the attitude of the Soil Survey Staff (1960) toward this classification system and classification systems in general. They suggest that 'Classifications are contrivances made by men to suit their purposes. They are not themselves truths that can be discovered". They further point out that classifications are not static things but need to change as knowledge expands.

As discussed earlier, the Soil Taxonomy authors note that it is a natural classification system. In such a system, as mentioned earlier, individuals were considered the basic unit of classification. From the concept of soils as natural bodies, it followed to define the soil individual. Cline (1963) discusses the relationship between the natural soils as we find them out of doors and our units of classification. Two terms and their relationships to each other were defined (Soil Survey Staff, 1975).

Pedon: The smallest area for which we should describe and sample the soil to represent the nature and arrangement of its horizons and variability in the other properties that are preserved in samples. (A unit of sampling).

Polypedon: A soil, the soil that we classify. It consists of contiguous similar pedons that are bounded on all sides by "non-soil" or by pedons of unlike character.

Thus, the soils that we classify are considered as contiguous units that grade to units that are different enough that we recognize them as having a different classification than the one under consideration. We estimate polypedon properties from a sample of that unit (a pedon). Thus, when we dig a pit or obtain soil materials from an auger boring, we are observing and measuring materials from our sampling unit. It is this material on which we record observations and make measurements, both in the field and laboratory. Once those measurements are made, we compare them to the taxonomic criteria to decide the classification to assign to the soil that we sampled. In practice, within a delineated mapping unit, we often have one or more similar polypedons and even included dissimilar units. Mapping units also possess, in addition to the properties of the polypedon, landscape properties such as slope and aspect. Some more recent philosophy (Holmgren, 1985) suggests defining the soil strictly by operational terms without invoking pedon and polypedon concepts.

IV. PUBLICATION AND USE OF SOIL TAXONOMY:

The objectives, logic, and assumptions of the new classification system were tested, beginning in 1951, through a series of "approximations" sent to pedologists in the U.S. as well as in other countries. Testing and modification of original ideas were sufficiently formulated by 1960 that the new classification system was presented at the International Congress of Soil Science in Madison, Wisconsin, and published in bound form as the 7th Approximation in that year. After additional refinements, the system was officially adopted for general use in the United States at the beginning of 1965. There was a period when proposals for improvement and modification were accepted but not acted upon in order to hold the system stable enough for general use and testing. Soil Taxonomy was published in bound form in 1975. Now proposals for modifications are processed through the Soil Taxonomy Policy Committee. Proposals for modification from the international community may be referred to ICOMS, international committees that deal with specific sets of problems or classes of soils. There is, therefore, an ongoing process by which changes will be made to Soil Taxonomy as needs for changes are recognized and our knowledge of pedology increases. Soil Taxonomy is, therefore itself, yet another approximation to be followed by others as our understanding becomes more complete. Bartelli (1975) summarized the future of Soil Taxonomy in the following manner:

> "Soil Taxonomy has the best chance for healthy evolution where there is a good mix of field mapping and a growing knowledge of soil genesis and soil behavior in the scientific community. Soil Taxonomy must be kept dynamic, it should react to new knowledge, especially when this knowledge encompasses soil behavior or our ability to predict response to management."

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DIAGNOSTIC SURFACE HORIZONS[1/]

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I. INTRODUCTION

Soil horizon is being used extensively as a means of identifying soils. It is a layer that is usually parallel to the soil surface of which some properties are products of soil-forming processes which makes it different from the layers just above and beneath it (Soil Survey Staff, 1951). These horizons are partly recognized by their own morphological and partly by certain properties that differ from those horizons below or above it.

In the earlier classification of Philippine soils, genetic horizons which are qualitative description about the changes that have occurred in the soil have been used. The diagnostic horizons on the other hand are defined in terms of quantified properties of the soil that are used to separate different soil taxa.

This paper was adopted from pages 14 to 64 of Soil Taxonomy.

II. DIAGNOSTIC SURFACE HORIZONS

The diagnostic surface horizons are usually referred to in Soil Taxonomy as EPIPEDON, from the Greek word epi which means over or upon the pedon which mean soil. These are therefore, the horizons that form at the surface and show darkening with organic matter or have eluviated, or rock structure has been destroyed.

It is possible that the epipedon may be covered by a thin alluvial or thin eolian deposits, but retain its identity as an epipedon or else it becomes a buried horizon if it lies below 50 cm or more.

1/ Paper presented at the XIV International Forum on Soil Taxonomy and Agrotechnology Transfer for the ASEAN region June 16-28, 1986 held in the Philippines.

The epipedon is not always the A horizon. It may include part or all of the B horizon if there is also darkening by organic matter here.

The properties of the epipedon is determined after mixing the upper 18 cm of the surface or the whole surface soil down to the bedrock, if it is thinner than 18 cm. The mixing process is required so as to insure no change in classification when the soil is plowed.

III. MOLLIC EPIPEDON

This surface horizon is relatively thick, dark in color, rich in humus, or one in which the exchange complex is dominated by cations and has a moderate to strong structure.

The mollic epipedon is believed to have formed from the deposition of organic residues where bivalent cations particularly Ca are abundant.

The mollic epipedon is defined with the following properties:

1. Strong structure such that the major part of the horizon is not both massive and hard or very hard when dry.
2. Have Munsell color value darker than 3.5 when moist and 5.5 when dry and chroma less than 3.5 when moist, unless there is more than 40 percent finely divided lime. But if the finely divided lime is more than 40 percent, the color value dry is waived because the finely divided lime masks their pigments, although the color value moist should be 5 or less.

   In short the mollic epipedon should be dark in color and low in chroma in the major part of its matrix.
3. Base saturation by NH_4OAc method is 50 percent or more.

4. It contains 2.5 percent or more organic carbon in the upper 18 cm if the color requirement is waived or if not, has at least 0.6 percent organic carbon throughout the specified thickness.

5. The mollic epipedon has various thickness requirements depending on certain conditions. After mixing it is the upper 18 cm of soil, or the whole soil if it is <18 cm to a rock, petrocalcic horizon, or duripan. Here, the other thickness requirements are associated with the presence or absence of a lithic contact, texture, lime, certain subsurface horizons, petrocalcic horizon or duripan.

6. Has less than 250 ppm of P_2O_5 or it either has increasing amounts of P_2O_5 in citric acid or has phosphate nodules in the epipedon.

7. It is moist in some parts for 3 months or more of the year in more than 7 years out of 10 years at times when the soil temperature is 5°C or higher at a depth or 50 cm if the soil is not irrigated.

8. The n-value is ≤ 0.7.

IV. ANTHROPIC EPIPEDON

The anthropic epipedon resembles the mollic epipedon in all properties except the higher limits on acid soluble P_2O_5 with or without the 50 percent base saturation, or the length of period during which it has available moisture.

V. UMBRIC EPIPEDON

The umbric epipedon meets the required properties of a mollic epipedon except that the base saturation by NH_4OAc <50 percent.

VI. HISTIC EPIPEDON

The histic epipedon is a layer at or near the surface that is saturated with water for 30 consecutive days or more in most years, although it may be artificially drained. It should also meet one of the following requirements.

Normally, it is a thin, horizon of peat or muck if not disturbed. However, when it is already plowed it contains high organic matter resulting from the mixture of peat and mineral materials.

It meets one of the following requirements:

1. The surface horizon consists of organic material at various proportions under certain conditions as defined in Soil Taxonomy, pages 17 to 18.
2. The plow layer is 25 cm or more thick and has 8 percent or more organic carbon if it has no clay or 16 percent or more organic carbon if it has 60 percent or more clay.
3. A layer of organic material that has enough organic carbon and is thick enough to satisfy one of the requirements in Item 1.
4. A surface layer of organic material < 25 cm thick that has enough organic carbon to satisfy the minimum requirements under item 2 after mixing the upper 25 cm depth.

VII. PLAGGEN EPIPEDON

This is a manmade surface horizon which is 50 cm or more thick and which has been produced by long continued manuring.

It is commonly identified with the presence of artifacts such as bits of brick and pottery throughout its depth. It normally shows spade marks and remnants of thin stratified beds of sand.

VIII. OCHRIC EPIPEDON

The ochric epipedon has too high color value or chroma, too dry, too little organic matter, too high a value or too thin to be mollic, umbric, anthropic, plaggen or histic. It is both hard and massive when dry.

IX. OTHER DIAGNOSTIC SOIL CHARACTERISTICS

ABRUPT TEXTURAL CHANGE - This is a change from an ochric epipedon or albic horizon to an argillic horizon. There is a required increase in clay content within a very short distance in depth.

If the clay content of the ochric epipedon or the albic horizon is less than 20 percent, the clay content should double within a distance in depth of 7.5 cm or less.

EXCHANGE COMPLEX DOMINATED BY AMORPHOUS MATERIAL - Amorphous material is a colloidal material that has all or most of the properties of allophane and it is generally amorphous under x-ray with the presence of crystalline materials to cause small and disordered peaks.

An exchange complex is predominantly amorphous if:

1. The exchange capacity of the clay at pH 8.2 is greater than 150 meq/100 g clay;
2. The ratio of 15-bar water content to clay is more than 1,
3. The pH_{NaF} is greater than 9.4 after two minutes if there is enough clay to have a 15-bar water content of 20 percent or more,
4. The organic carbon content is more than 0.6 percent;
5. The DTA shows a low temperature endotherm; and
6. The bulk density of the fine-earth fraction is less than 0.85 g/cc at 1/3 bar tension.

X. COEFFICIENT OF LINEAR EXTENSIBILITY (COLE)

The Cole value is the ratio of the difference between the moist length and the dry length of a clod to its dry length. The expression is (Lm-Ld)/Ld where Lm is the length at 1/3 bar tension and Ld is the length when dry.

It can be calculated from the difference in bulk density of the clod when moist and when dry. It can also be measured from the shrinkage of a sample that has been packed at field capacity into a mold and then dried.

DURINODES - Durinodes (from L. durus, hard and nodus, knot) are weakly cemented with SiO_2 to indurated nodules.

GILGAI - This is the microrelief that is tupical of clayey soils having a high coefficient of expansion with changes in moisture content. The microrelief consists of enclosed microbasins and microknolis in nearly level areas or of microvalleys and microridges in rolling areas. Here, the height of the micrordigas ranges from a few centimeters to 1 m or more but rarely higher than 2 m.

LITHIC CONTACT - This is a boundary between soil and coherent underlying material having a hardness of 3 or more in the Mohs scale but does not include a duripan or a petrocalcic horizon and it must be within 50 cm of the surface of a mineral soil to be diagnostic.

MOTTLES THAT HAVE CHROMA OF 2 OR LESS -- Mottles are spots of contrasting colors. For example, a soil having gray color in the matrix with a few spots of red and brown. Here, the mottles are the spots of red and brown. It refers to colors in a horizon in which parts have chroma of 2 or less, moist, and value, moist of 4 or more whether or not that part is dominant in volume or whether or not it is a continuous phase surrounding spots of higher chroma. The part is excluded from the meaning if all the horizon has chroma of 2 or less or if no part of the horizon has chroma as low as 2.

The mottles that have chroma of 2 or less also means that the horizon is saturated with water at some period of the year or the soil is artificially drained.

n VALUE - This value refers to the relation between the percentage of water under field conditions and the percentages of inorganic clay and humus. It can be calculated for mineral soil materials that are not thixotropic by the formula:

$$n = (A - 0.2R)/L + 3H)$$

Where: A = the percentage of water in the soil, calculated on a dry-soil basis.

R = the percentage of silt plus sand

L = the percentage of clay

H = the percentage of organic matter (organic carbon x 1.724).

The critical n value of 0.7 can be approximated closely in the field by a simple test of squeezing the soil in the hand. If the soil flows with difficulty between the fingers, the n value is between 0.7 and 1.0. It is 1 or more, if the soil flows easily between the fingers.

ORGANIC SOIL MATERIALS - Organic soil materials either (a) are saturated with eater for long periods or artificially drained and have 18 percent or more organic carbon if the mineral fraction is 60 percent or more clay, 12 percent or more organic carbon if the mineral fraction has no clay, or a proportional amount of organic carbon between 12 and 18 percent if the clay content is between zero and 60 percent, or (b) are never saturated with water for more than a few days and have 20 percent or more organic carbon.

Item a above are the peats and muck while those in item b are the litters or 0 horizons.

PARALITHIC CONTACT - This means lithic like which refers to the boundary between soil and continuous coherent underlying material which has a hardness of less than 3 by Moh's scale, if it is a single material . But if the underlying material is not a single material, chunks of gravel size can be broken out disperse more or less completely during 15 hours of end-over-end shaking in water or in sodium hexametaphosphate solution. If it is moist, it can be dug with difficulty with a spade.

PARTICLE-SIZE CLASSES - Classes of soils based on both the fine earth fractions and the rock fragments in selected horizons or within arbitrary limits of depth. It is used to define a number of taxa as well as it is used as differentiate at the family level.

PERMAFROST - Is a layer in which the temperature is parennially at or below 0°C, whether the consistence is very hard or loose.

PETROFERRIC CONTACT - A word petroferric is derived from the German word Petra which means rock, and the Latin word ferrum which means iron, implying ironestone. Hence, the Petroferric contact is a boundary between soil and a continuous layer of indurated material in which iron is an important cement and organic matter is absent or is present only in traces. To be diagnostic, it is required that it must be continuous within limits of a pedon but may be fractured if the average lateral distance between fractures is 10 cm. The indurated layer differs from a placic horizon and from an ortstein by the absence of organic matter.

PLINTHITE - This is derived from Gr. plinthos, meaning brick. It is an iron-rich, humus poor mixture of clay with quartz and other diluents. Plinthite occurs as dark red mottles, which usually are in platy, polygonal, or reticulate patterns. It changes irreversibly to an ironestone hardpan when exposed to repeated wetting and drying, especially when exposed also to heat from the sun. It is called an ironestone after irreversible hardening.

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It does not form a continuous phase if present in small amounts in the soil, but if a large amount is present, it may form a continuous phase.

POTENTIAL LINEAR EXTENSIBILITY -- This is the sum of the products for each horizon, of the thickness of the horizon in centimeters and the COLE of the horizon.

SEQUUM: NUMBER AND KIND -- This is a sequence of an eluvial horizon and its sub-adjacent B horizon, if one is present. This is illustrated by an Albic horizon and a spodic horizon immediately underlying it.

SLICKENSIDES -- These are polished and grooved surfaces that are produced by one mass sliding past another. They are very common in swelling clays.

SOFT POWDERRY LIME - This is the translocated authogenic lime that is soft enough to be cut readily with the finger-nail. It is the lime that is precipitated in place from the soil solution and not from the parent material.

SULFIDIC MATERIALS -- These are waterlogged minerals or organic soil material containing 0.75 percent or more sulfur (dry weight). They are mostly in sulfide forms and they have less than three times as much $CaCO_3$ equivalent as sulfur. The sulfidic materials accumulate in a soil that is permanently saturated, generally with brackish water.

THIXOTROPHY - This is a property of soil that relates to a reversible gel-sol transformation under isothermal shearing stress following rest. It is tested in the field by pressing a bit of wet soil between the thumb and forefinger wherein, at first it resists deformation, but with increasing pressure, the soil is molded and deformed, and with more pressure, the soil suddenly changes from plastic solid to a liquid, and then the fingers skid.

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Here, the liquified soil sets back to its original solid state after a second or two.

TONGUING - Penetrations of bleached material that has the color of an albic horizon in an argillic or a natric horizon. Here, the vertical penetration is more than 5 cm and the horizontal dimension is ranging from 5 mm to 15 mm or more depending on the texture of the argillic or natric horizons. The penetrations must also occupy more than 15 percent of the matrix of some part of the argillic or natric horizon.

INTERFINGERING - This concerns the inter-fingering of albic materials consisting of penetrations of albic materials into an underlying argillic or natric horizon primarily along vertical faces of peds and to a lesser degree along horizontal faces.

Interfingering of albic materials meet certain requirements in a horizon that is 5 cm or more thick such as (a) half or more of the matrix consists of peds of the argillic or natric horizon, (b) albic materials are thicker than 2 mm on vertical faces, but are too thin to be tongues, and (c) clay skins are present in the peds.

Albic materials also meet certain color requirements.

WEATHERABLE MINERALS - These are either (a) clay minerals consisting of all 2:1 lattice clays except the aluminum-interlayered chlorite but includes others that are not of clay size minerals (0.02 to 0.2 mm in diameter) such as feldspars, feldspathoids, ferromagnesium minerals, glass, micas, zeolites, and apatite.

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SOIL MOISTURE AND TEMPERATURE REGIMES[1/]

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INTRODUCTION:

This soil temperature and moisture regimes discussion is based partly on discussions by Dr. Guy Smith in response to questions assembled and asked by Dr. Leamy on the rationale for Soil Taxonomy. The discussions took place from 1977 to 1980 and were first published in New Zealand Soil News and later in the United States in Soil Survey Horizons. Soil Taxonomy itself provided most of the remaining source material. The objective of this presentation is to discuss the general rationale related to the use of moisture and temperature regimes and how they were placed into the framework of Soil Taxonomy.

The question has been asked why climatic parameters, moisture and temperature, were used in Soil Taxonomy when these are considered by some soil scientists as factors external to the soil. Dr. Smith granted that the moisture regime relates to climate imperfectly, pointing out that on a given farm, some soils are wetter than others. He emphasized, however, that soil moisture regimes strongly influence soil development and thus their properties. He pointed out what we commonly observe---that both moisture and temperature generally determine the vegetation to be found in a given locale. In addition, he noted the importance of temperature on the rate of chemical processes and, thus, on the rate of weathering of minerals in soils. We recall from basic chemistry that an increase of 10°C doubles the reaction rate of substances in solution. By this chemical relationship, temperature and moisture are both directly implicated in soil weathering. Jenny recognized these ideas and listed climate as one of the factors of soil formation. This relates to a basic assumption used by Dr. Smith in Soil Taxonomy. That assumption is that properties that result from genesis (such as clay skins) or are factors in genesis (such as climatic factors) which are causes of other properties are the factors that should be used in the definitions. As we will see later, these properties were considered important enough to be used at very high taxonomic levels.

Moisture and temperature are, to a large degree, interdependent in their influence in soil science and in nature generally. We will eventually discuss their interactive influence somewhat more specifically, but before we do that, let's consider how they are used individually as criteria in Soil Taxonomy.

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Soil moisture regimes are based on the amount of time and the times of the year that a portion of the soil, defined as the moisture control section, is moist. The moisture control section is an arbitrary index depth used to compare soil moisture regimes. In a given soil, the moisture control section is defined as the depth between the lower boundary of wetting by 2.5 cm in water 24 hours on a dry soil and the lower boundary of wetting by 7.5 cm of water in 48 hours, also on a dry soil. This generally equates to depths between 10 and 30 cm for fine textured soils (fine-loamy, coarse-silty, fine-silty, or clayey), between 20 and 60 cm for coarse-loamy soils, and between 30 and 90 cm for sandy soils. These depths can be estimated from water retention and porosity data.

Specific criteria for the moisture regimes defined in Soil Taxonomy list the number of days and the times of the year when soils of a given moisture regime are moist or dry. Only the general concepts are listed here:

1. Aquic - in most years, the soil is saturated with oxygen-depleted water during part of the growing season; peraquic if a continuous condition (such as tidal marshes).
2. Aridic (also Torric) - moisture control section dry most of the growing season.
3. Udic - no part of the moisture control section may be dry for more than 3 months, cumulative. The most favorable for plant growth; perudic if a continuous condition.
4. Ustic - moisture control section dry in some parts more than 90 days, cumulative. Intermediate between Udic and Aridic.
5. Xeric - Mediterranean Climates (dry during the growing season).

Let's look now at the soil orders and suborders and observe where the moisture regimes are used.

Alfisols

- Aqualf
- Boralfs
- Ustalfs
- Xeralfs
- Udalfs

Aridisols

- Argids
- Orthids

Oxisols

- Aquox
- Torrox
- Humox
- Ustox

Spodosols

- Aquods
- Ferrods
- Humods

Mollisols

- Aquolls
- Rendolls
- Xerolls
- Borolls
- Ustolls
- Udolls

Vertisols

- Xererts
- Torrerts
- Uderts
- Usterts

Ultisols

- Aquults
- Humults
- Udults
- Ustolts
- Xerults

Because of the large influence of a reducing moisture regime on a soil, in orders where they occur, the aquic suborder is listed first in the key. Looking at other orders, one of them, Aridisols, is defined primarily by moisture regime. Moisture regimes other than aquic play a major role in the definitions of suborders of six additional orders. Histosol suborders are primarily based on degree of decomposition and are, as a whole, formed under moist conditions, so again moisture is involved.

Since Entisols and Inceptisols are less highly developed, except for Aquepts and Aquents, suborders are based on properties that cause them to be less developed. Moisture regimes, however, are used at the great group level. For example, Ustochrepts, Xerochrepts, Ustorthents, Torriorthents, etc.

We have described the central role that soil moisture plays in the framework of Soil Taxonomy. Now let's look at the role and definitions of soil temperature regimes.

Perhaps temperature more directly affects the biology and chemistry of the soil than moisture because, given adequate moisture, temperature delimits length of growing seasons, rates of soil weathering and microbial activity. A caution was expressed by Dr. Charles Kellogg (1941). He wrote that climate within the soil is unlike that above the soil and that, loosely speaking, as the climate "enters the soil", it is modified by soil conditions. Soil temperatures, although different from air temperatures as Dr. Kellogg pointed out are, however, usually predictable within practical limits from air temperature data.

The authors of Soil Taxonomy verify the degree of modification from air to soil temperature in some detail by graphic and tabular data. They discuss daily and seasonal fluctuations, the functions of soil depth, soil moisture, soil cover, slope, and variations due to latitude. From this knowledge, they point out relationships that we find used in the rationale of soil temperature regime definitions. Air temperatures are useful to estimate soil temperatures if they cannot be measured directly.

Since the soil temperature gradient is essentially linear in the upper meter and temperatures at 50 cm fluctuate little relative to diurnal air temperature fluctuations, 50 cm was chosen as the soil depth on which soil temperature regimes would be based. Temperature regimes are based on mean annual temperatures and differences between winter and summer mean temperatures. Two generally parallel groups are defined, those of the temperate regions where summer and winter temperatures usually differ more than 5°C and those that have little (< 5°) seasonal fluctuation, mostly in the intertropical zone (denoted by the prefix "iso"). The generalized definitions are:

1. Pergelic - continuously frozen.
2. Frigid/Isofrigid - mean annual temperature < 8°C.
3. Cryic - temperature is essentially isofrigid but varies with "O" horizon cover and moisture.
4. Mesic/Isomesic - mean annual temperature is equal to or more than 8°C but less than 15°C.
5. Thermic/Isothermic-mean annual temperature is 15°C or more but less than 22°C.
6. Hyperthermic/Isohyperthermic - mean annual temperature is 22°C or higher.

Examples of temperature variations in locations at different distance from the equator are shown in Table 1. The similar mean annual temperature in the central United States and Ecuador but with different summer and winter temperature patterns emphasizes the utility of iso temperature regimes.

Table 1. Comparison of Temperature Ranges by Latitude.

CITY AND STATE	LAT.	MEAN ANNUAL	MEAN JAN.	MEAN JULY	TEMP. REGIME
		DEGREES C			
Omaha, Nebraska	41°18'N	10	- 4.6	25.6	Mesic
Key West, Florida	24°31'N	24	21.0	28.4	Hyperthermic
Manila, Philippines	1[illegible]°35'N	[illegible]	25.1	27.3	Isohyperthermic
Cotopaxi, Ecuador	[illegible]	10	9.8	10.3	Isomesic

The concept of iso temperature regimes was drawn from the experience that limitations on plant growth are quite different in the intertropical regions from those of the temperate zones. Dr. Smith explained that cessation of plant growth in temperate regions is determined by temperature, whereas, in intertropical regions, it is determined by moisture. Soils in areas in which plant growth is controlled by temperature receive large organic matter "flushes" at about the same time of the year. In the intertropical areas with udic moisture regimes, on the other hand, organic matter is added evenly throughout the year. Dr. Smith felt that there were different genetic effects of a large amount of organic matter coming over a short period. and the same amount coming over a full year. Since there may also be cessation of plant growth in ustic moisture regimes in the tropics (moisture control of plant growth) with similar resulting organic matter "flushes", the Tropic great groups are primarily restricted to udic moisture regimes, although there are few exceptions.

The selection of the temperature criteria was based on isotherms in the United States that coincided with growth of certain commercial crops. The 8° temperature isotherm generally separates winter and spring wheat growing areas and also areas between where corn (maize) can be grown for grain and where it can be grown for silage only. Cryic soils were separated with the thought that they were too cold to be cultivated. The 15° limit was chosen because that isotherm is the northernmost limit of where cotton is grown. The 22° isotherm is the northern extent of the citrus and winter vegetable belt. For convenience, the same mean annual temperature limits were used for the isotemperature regimes. When Soil Taxonomy was published, the limits also seemed reasonable for the intertropical region. Since more experience has been gained, it appears that 10° might be a better break between isofrigid and isomesic. It also appears that hyperthermic and isohyperthermic regimes could be combined. Another suggestion is to separate a higher temperature regime (megathermic) at 28°C. The placement of temperature regimes within the suborder and great framework of Soil Taxonomy can be understood by observing where formative names denoting temperature regimes occur on pages 86 and 87 tables of Soil Taxonomy. Table 2 summarizes those suborders and great groups.

Table 2. Soil Temperatures at the Great Group Level

Alfisols	**Inceptisols**
Tropaqualfs	Cryandepts
Boralfs	Cryanquepts
Cryoboralfs	Tropaquepts
Tropudalfs	Tropaquepts
	Cryochrepts
	Tropepts
	Cryumbrepts
Aridisols	
Entisols	**Mollisols**
Cryaquents	Crayaquolls
Tropaquents	Borolls
Cryofluvents	Cryoborolls
Cryorthents	
Troporthents	**Spodosols**
Cryopsamments	Cryaquods
Tropopsamments	Tropaquods
	Cryohumods
	Tropohumods
	Cryorthods
	Troporthods
Histosols	**Ultisols**
Borofibrists	Tropaquults
Cryofibrists	Tropohumults
Tropofibrists	Tropudults
Borofolists	
Cryofolists	
Tropofolists	
Borohemists	
Cryohemists	
Tropohemists	
Borosaprists	
Cryosaprists	
Troposaprists	

Primarily, Cryic and Tropo elements occur as part of great group names. Trop is also used as a suborder element with Inceptisols (Tropepts). When temperature regimes are not named or implied in suborders or great groups, they are named as part of the family designation. The soil temperature regimes, for example, are not named in families of Cryic great groups. They are, however, named in families of Trop great groups because although Trop designates uniform temperatures throughout the year, it does not designate the mean annual temperature grouping (i.e, Isomesic, Isothermic, etc.). As with moisture regimes, temperature regimes have a prominent role in the framework of Soil Taxonomy.

As mentioned earlier, it is appropriate to discuss soil moisture and temperature regimes together since moisture and temperature act interdependently on their effects on plant growth and soil genesis.

Some example interrelationships follow. The most highly weathered soils (Oxisols, Ultisols) occur where temperatures are high (thermic or hotter) and moisture regimes are Udic (and sometimes Ustic). Thermic temperatures are sufficiently high to enhance chemical and biologic activity while Udic moisture regimes provide ample but not excessive moisture for chemical and biologic activity.

At the cold temperature extreme, Pergelic (continuously frozen), essentially no soil weathering occurs because low temperatures per se impede biological activity and moisture is ineffective because it is frozen. Further, since water cannot move, the transport mechanism that contributes to soil development is non existent.

High temperatures (thermic and warmer) can have no beneficial plant growth influence when moisture is limited (aridic). With minimal plant growth, other biological activity is highly impeded and additionally, little chemical activity occurs, again with little soil development as the result. Excessive moisture (aquic moisture regimes) also restricts biological activity. The result is commonly a larger accumulation of organic carbon. An extreme expression of this condition may result in the formation of organic soils.

As discussed earlier, patterns of moisture or temperature are also important. We mentioned that in the intertropical regions where temperatures are warm enough, plants can grow all year if there is adequate moisture but, when moisture is limited during parts of the year (Ustic), plants grow only when there is adequate moisture (unless there is irrigation). Temperature extremes likewise limit plant growth to warm times of the year even though moisture may be available for plant growth. We also observe the effects of moisture and temperature extremes by evidence of cracking and alternate swelling in soils. The evidence occurs as slickensides.

To summarize, we have discussed the rationale and criteria for soil moisture and soil temperature regimes. We also discussed the central role of soil moisture and temperature properties within the framework of Soil Taxonomy. We have also seen that functions of moisture and temperature are interdependent in soil formation and plant growth as they are throughout nature.

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SOIL LABORATORY ANALYSIS FOR SOIL CLASSIFICATION[1/]

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I. INTRODUCTION

In soil survey, the surveyor ideally would record and map the values of all relevant properties all over the survey area. This is rarely done, however, in actual practice for reason of economy, time and limited manpower. Hence, soil survey is usually simplified by the surveyor by no longer looking and mapping all values, but only the class limits.

In soil survey, the soil map should have a purpose. The map should help solve a given problem or provide information on those properties of the soil that may affect the intended utilization of the soil.

Having identified the purpose and knowing the particular problems, the soil surveyor begin to determine which soil properties or aspect of soil behaviour causes or is related to the problem. These are the properties that should be mapped rather than mapping the survey area in intricate details, only to find out later that the problem is only related to only one or two soil properties.

It is not enough, however, that the above requisites are met. The surveyor must also know his own limitations. He should recognize that he himself, is not solving the problem. In soil survey, he can only ascertain the delineation and distribution in the survey area of the desired soil properties that are related directly or indirectly to the problem. He records the properties and present them

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using a classification map and the legends. That map becomes a means or a tool with which the problem solver gets the information about the desired soil conditions without actually going to the problem area to see for himself.

II. THE NEED FOR SOIL ANALYSES

Relevant soil properties for survey purposes are quite expensive and/or laborious to determine and many of them can only be determined in the laboratory. The data will enable the surveyor to interpolate soil class boundaries afterwards.

There are many uses of soil analyses. It is used in soil survey, in the inventory of soil resources, in evaluating soil limiting properties, in soil genesis, in soil fertility, etc.

For our purpose, we relate soil analyses with soil survey and classification. We use soil analysis to characterize quantitatively the properties of some or most of the mapping units. One can also adjust his survey procedures if laboratory data are available before the start of the survey. In actual survey, the data can be used to establish relationships between soil properties and the landscape.

Soil laboratory data are also useful in arriving at correct classification of soils in various soil classification systems.

The data is also used in detailed land evaluation as well as in the development of capability classification of the land.

In land resources inventory, soil laboratory data can be used to develop soil property inter-relationships which will help predict another property of the soil (Eswaran, 1977).

III. KINDS OF ANALYSES

The purpose and kind of survey dictates the types of analyses to be done.

Eswaran (1977) identified three classes of soil analyses in relation to the purpose of the survey. Class I are the analyses required in Soil Taxonomy. Class II are the analyses performed for specific purposes or problems, and Class III for genetic studies.

Tables 1, 2, and 3 enumerates the types of laboratory analyses in relation to survey objectives.

Table 1. Class I. Analyses required in Soil Taxonomy (Eswaran, 1977).

1A. General analyses required on all horizons on all profiles.

1. Particle size distribution by pipette method
2. Organic carbon, nitrogen
3. Cation Exchange Capacity (NH_4OAc, pH 7)
4. Exchangeable bases (Ca, Mg, Na, K)
5. pH in H_2O and 1N KCl (1:1)
6. 1N KCl - extractable Al
7. $BaCl_2$ - triethanolamine (pH 8.2) H_+
8. CBD - extractable Fe_2O_3

1B. Analyses required on a few selected profiles to test specific requirements of Soil Taxonomy

1. Bulk density - for the Andepts and the "Hum" sub-orders and GG
2. pH in 1N NaF - Andepts and Spidosols
3. 15 bar water - Inceptisols, Alfisols, content Ultisols and Oxisols
4. CEC by 1N NH_4CL - Oxisols
5. COLE value - Vertisols, Vertic SG
6. Conductivity - Aridosols, some families
7. $CaCO_3$, $CaSO_4$ - Aridosols, Mollisols

1C. Analyses required on a few selected horizons to test specific requirements of Soil Taxonomy

1. P_2O_5 -- Anthropic epipedon
2. pp Ext. Fe, Al - Spodic horizon
3. Fine/coarse clay ratio -- Argillic horizon
4. Mineralogy of clay -- Argillic horizon
5. Mineralogy of fine sand - Soil families

Table 2. Class II. Analyses performed for specific objectives or problems.

IIA. Physical and engineering properties

1. Infiltration rate
2. Permeability
3. Available water
4. Bearing capacity
5. Other engineering properties

IIB. 1. Salinity, alkalinity

2. pH fresh, dry or with oxidisers
3. Toxic substances (arsenic, boron, nickel, Chromium, sulphides, Iron)
4. Fertility-related properties employing different kinds of extracts
5. EL

IIC. Chemical properties on water at site or incoming water.

1. Suspended solids
2. Dissolved salts (electric SAR)
3. Toxic substances (B, Mg, Na, Cl^{--}, SO_4^{--}, CO_3^{-}, HCO_3^{-})
4. pH

Table 3. Class III. Analyses performed for genetic studies

1. Extraction of dissolution techniques
2. Mineralogical
3. Micromorphological
4. Equilibration

The above are performed in addition to some or all of Class I and II analyses.

IV. SOIL ANALYSES IN THE PHILIPPINES

Soil testing started in this country in 1939, in the Division of Soil Survey and Conservation, now the Bureau of Soils. The kind of analyses were concerned in the determination of total nitrogen, phosphorus and potassium. The data were mostly used for soil survey and for soil fertility assessment.

Rapid soil testing for soil fertility assessment was initiated in 1947.

In 1963-1968, the Soil Fertility Survey and Research Project of FAO/UNDP-BS introduced some analytical changes but mainly for the assessment of soil fertility. However, this was followed by the soil survey classification project of the FAO/UNDP-BS in 1969-1973. The analytical procedures began to be modified/introduced for survey and classification purposes. Upon the termination of the soil survey and classification project, it was followed by the Soil and Land Resources Appraisal and Training Project in 1974-1978 still under the FAO/UNDP-BS.

The establishment of regional and provincial soil laboratories that started in 1964 continued to 1978 that resulted to 36 soil laboratories distributed throughout the country.

It was in 1974-1978 that analytical procedures as prescribed in Soil Taxonomy were gradually introduced in this country. This was the beginning of the generation of soil data for taxonomic classification in the Philippines.

When the last FAO/UNDP project was completed in 1978, a more or less complete set of soil survey laboratory instruments were left to continue the project.

With time, however, many of the trained personnel to handle the instruments have either retired or resigned and since then the training of laboratory personnel was at a stand-still. Personnel were only taught how to use the equipments by rarely how to maintain them. Worst, many of the models are phased out so that spare parts are difficult to secure. To continue the use of the equipment, one or two of the same instruments were dis-assembled and used as source of spare parts to make the others work. The process continued until only very few are new left working.

Eswaran (1977) listed the essential equipment for a soil survey laboratory includes (a) AA spectrophotometer, (b) spectrophotometer (c) pH meter, (d) EC meters, (e) balances, (f) hot plate, (g) stirrers, (h) water-bath, (i) ovens, (j) furnaces, (k) glasswares.

All of these are provided in the central soil laboratory at Manila including some optional equipment such as: flame photometer, centrifuge and such expensive instruments as the X-ray diffractometer, DTA-TGA thermoanalyses. We also have complete sets for the determination of particle size distribution by pipette and buoyoucous methods, complete set for aggregate stability determination, hydraulic conductivity and even a polarizing microscope. Nobody around are familiar now in the use of these sophisticated instruments.

V. CONSTRAINTS ON SOIL ANALYSES

1. Lack of qualified laboratory personnel.
2. Phohibitive cost of chemicals.
3. Ban on purchase of new equipment.
4. Phased-out models of instruments and lack of available spare parts.

VI. CONCLUSION

Soil anlyses for soil survey and classification has been adequately started in this country for sometime. Most if not all of the necessary analytical instruments are available. However, there have been limited support for the maintenance and the expertise to handle the instruments have waned so that some of the more expensive ones are still in good use but nobody to operate them.

There, is therefore, a need to train laboratory personnel not only on analytical procedures and techniques, but also technicians to operate and maintain the instruments.

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SOIL ANALYSIS FOR SOIL SURVEYS[1/]

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INTRODUCTION

Although a useful and necessary component of soil survey report is profile description and soil analysis, many reports tend to omit this information. In some cases no analyses were performed due to lack of facilities or the analysis were not complete at time of publication of the report.

As the soil report is the only means that the soil surveyor has to communieate his findings to the users, it is necessary that he defined his units in the most unambiguous terms. Soil analyses aid him to do this and the quality of the report is greatly enhanced if all his mapping units are described in morphological, geographical, and physico-chemical terms.

There are few guidelines to assist the soil surveyor in deciding the number of pedons to be described and analyzed, the type of analysis to be performed, and perhaps also the use of this information in his report. This contribution attempts to evaluate some of these questions and provide some suggestions.

WHY SOIL ANALYSES

Soil analyses in soil survey reports are included to define in numerical terms the physico-chemical properties of the major soils of the area. The morphological descriptions and physico-chemical properties are considered to be representative samples of the area, the measured properties are extrapolated to generalize the behavior or response of the soil to specific uses.

1/ Paper presented at the XIV International Forum on Soil Taxonomy and Agrotechnology Transfer for the ASEAN region, held in the Philippines.

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The several different uses of soil analyses are:

<u>In Relation to the Soil Survey Reports</u>

1. The characterize numerically the properties of some or all of the mapping units. If some data are available at the commencement of the survey or during the early part of the survey, they enable the surveyor to calibrate himself. At the end of the survey they enable him to establish relationships between soil properties and other morphological and landscape parameters.
2. To aid in the correct classification of the soil and enable others to place the soil in other taxonomies.
3. To serve as a basis for more detailed evaluation of the soils; preliminary information on nutrient, physical, or other limitations needed for developing a capability classification may be extrapolated from such analyses.

<u>In Relation to Developing a Resource Inventory of the Region or Country</u>

1. For correlation purposes, it is necessary to build up a soil data bank. Creating new series or grouping old ones is then done on a rationale basis.
2. To use in other areas where no data is available but physiographic conditions indicate possibility of similar soils.
3. To develop soil property interrelationships which enable one to predict a property which is difficult or incovenient to measure.

<u>In Relation to Evaluating Limiting Properties</u>

1. To determine levels of elements which may be toxic or deficient or levels of soil conditions which may be limiting to use of the soil. As the surveyor is

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frequently called upon to assess the potentials of the soils, he needs these limits.

2. To delineate soils which require various levels or investment for their economic utilization.

To Relation to Their Genetic Properties

1. To aid in an understanding of their composition and formation. These investigations are generally the most comprehensive but in some cases tend to deal with the unique or the obscure.

2. To evaluate the changes induced by management practices and thereby determine optimal types of management.

TYPES OF ANALYSES

The objectives of the survey determine the types of analyses to be performed. Soil analyses are grouped into classes (Table 1) to reflect these objectives.

Class Ia analyses are those which are necessary to classify the soil in most taxonomies and form the minimum type of analyses that should accompany profile descriptions. In some cases Ib or Ic analyses are necessary but an estimate of some of the latter may be made from Ia analyses. Every soil survey laboratory must be quipped to perform most of all of Class I analyses.

Class II are performed for special surveys. The number of samples is usually large and samples may be taken at specific depth intervals in the soil. Auger samples are generally employed and samples from unit areas may be bulked to reduce sampling error. Single property maps are based on such data.

Class III analyses generally do not appear in soil survey reports of LDCs as these are considered "academic". These studies are useful to develop concepts and build up classification systems.

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Table 1. Types of analyses in relation to objectives

<table>
<tr><th>CLASS I

ANALYSES REQUIRED BY SOIL TAXONOMY</th><th>CLASS II
ANALYSES PERFORMED FOR SPECIFIC OBJECTIVES OR PROBLEMS. (GENERALLY PERFORMED ON SITE, OR ON UNDISTURBED SAMPLES OR ON AUGER SAMPLES.)</th><th>CLASS III

ANALYSES PERFORMED FOR GENETIC STUDIES</th></tr>
<tr><td>a. General analyses required on all horizons on all profiles

1. Particle size distribution
2. Organic carbon, nitrogen
3. Cation exchange capacity (NH_4OAc, pH 7)
4. Exchangeable bases: Ca, Mg, Na, K
5. pH in H_2O and 1N KCl (1N)
6. IN KCL-extractable Al
7. $BaCl_2$ - triethanolamine (pH 8.2) H^+
8. CBD-extractable Fe_2O_3</td><td>a. Physical and engineering properties

1. Infiltration
2. Permeability
3. Available water
4. Bearing capacity
5. Other engineering properties</td><td>1. Extraction or dissolution
2. Mineralogical
3. Micromorphologi[cal]
4. Equilibration</td></tr>
<tr><td>b. Analyses required on a few selected profiles to test specific requirements of Taxonomy

<table><tr><th><u>Analysis</u></th><th><u>Examples in Taxonomy where required</u></th></tr><tr><td>1. Bulk density</td><td>Andepts, 'Huma' sub-orders and GG</td></tr><tr><td>2. pH in IN NaF</td><td>Andepts, Spodosols</td></tr><tr><td>3. 15 bar H_2O</td><td>Inceptisols, Alfisols, Ultisols Oxisols</td></tr><tr><td>4. CEC by IN NH_4Cl</td><td>Oxisols</td></tr><tr><td>5. COLE value</td><td>Vertisols, Vertic SG</td></tr><tr><td>6. Conductivity</td><td>Aridisols, some families</td></tr><tr><td>7. $CaCO_3$, $CaSO_4$</td><td>Aridisols, Mollisols</td></tr></table></td><td>b. Chemical properties on soil

1. Salinity. alkalinity
2. pH fresh, dry, or with oxidisers
3. Toxic substances (Arsenic, Boron, Nickel, Chromium, Sulphides, Iron)
4. Fertility-related properties employing different kinds of extractants
5. Eh</td><td>(The above are performed in addition to some or all of Class I and II analyses.)</td></tr>
<tr><td>c. Analyses required on a few selected horizons to test specific requirements of Taxonomy

<table><tr><td>1. P_2O_5</td><td>Anthropic horizon</td></tr><tr><td>2. Pyrophosphate-extractable Fe, Al</td><td>Spodic horizon</td></tr><tr><td>3. Fine/coarse clay ratio</td><td>Argillic horizon</td></tr><tr><td>4. Mineralogy of clay</td><td>Argillic horizon</td></tr><tr><td>5. Minerology of fine sand</td><td>Soil families</td></tr></table></td><td>c. Chemical properties on water at site or incoming water

1. Suspended solids
2. Dissolved salts (electric, SAR)
3. Toxic substances (Boron, Magnesium, Lithium, Cl^-, SO_4^{--}, CO_3^{--}, HCO^-)
4. pH</td><td></td></tr>
</table>

NUMBER OF PROFILES OR HORIZONS TO BE ANALYZED

The number of profiles to be analyzed is a function of the scale of the map and the objectives of the survey . Table 2 attempts to determine the basis for selection of profiles for characterization and the types of analyses to be performed. Profiles are selected to show not only the basic characteristics but also the range in properties.

Most profiles are sampled to a depth of 2 m unless particuhar soil conditions or objectives require shallower or deeper samples. The normal procedure is to sample morpho-genetic horizons and when a horizon is thicker than 25 cm, one sample is taken for each 25 cm.

CONSIDERATIONS ON COST OF SOIL ANALYSES

Many a soil surveyor hesitates to send in soil samples for analysis due to the costs involved, particularly if done by a commercial lab. This is a limiting factor with respect to the number and types of analyses.

Cost of soil analysis must be considered in relation to:

1. coist of the whole soil survey, and
2. cost of development of the area

Cost of the soil survey is indicated on a ha basis and in many LDCs, this does not exceed 10 or 20 cents per ha (for a map of 1:63,000). No estimate of cost per ha of soil analysis is available but this is not expected to be more than 10% of the cost of the soil survey. However, both the cots are a small fraction of the total developmental costs of the area.

For example, in Malaysia it costs about $500 per ha to bring an area into rubber or oil-palm. The benefits accrued due to the recommendation of the soil survey for outweigh the cost of soil survey and soil analyses. Consequently, cost of soil analyses should not limit the number or types of analyses within the limits suggested in Table 2. Obviously a survey can use analytical data obtained in earlier work.

QUALITY OF SOIL ANALYSES

Quality control is very important and there are several ways to attain this:

1. Inter-laboratory cross-checks,
2. Sample duplication, and
3. Statistical approach.

1 and 2 are followed by some labs. Quality control deals with not only the laboratory but also the surveyor. When the same soil series is identified in different parts of the country, it is necessary to verify the similarity of their physico-chemical properties. The coefficient of variation (CV) is a good parameter to evaluate this. The acceptable CV is determined to a large extent by the property in question. Beckett et al. (1971) have provided some levels.

SOIL ANALYSES IN LDCs

Constraints to Good Analyses in LDCs

Many soil data from LDCs tend to be less reliable for several reasons:

1. Lack of qualified lab personnel. Training of lab personnel in analytical methods should be an equally important contribution of aid programs. FAO personnel in Thailand, faced with this problem, have organized in-service training programs and provided a manual which gives all details.
2. Equipment. Two situations generally prevail. If there was a technical aid project, the labs are equipped well, but as lab personnel are not trained to maintain equipment and spare parts are difficult to get, the equipment is no longer used after the departure of the experts. In the absence of a foreign project either the labs are bare or stocked with the most fancy equipment. However, a survey by FAO of more than 225 labs in LDCs (Brogan et al., 1965) indicated that most of the labs were well equipped to perform the general analyses required for soil surveys.

Table 2. Selection of profile for analyses and types of anàlyses to perform.

KINDS OF SOIL SURVEY	SCALE PUBL. MAP	SELECTION OF PROFILES FOR ANALYSES	TYPES OF ANALYSES
Class A	<1:7,920	Minimum one per taxonomic unit plus other samples to show limiting or specific characteristics	All or part of Class I or II
Class B	7,920 - 24,000	Minimum one per dominant soil series or equivalent	All or part of Class I or II
Class C	24,000 - 62,500	Dominant soil families or equivalent	Class Ia with or without others
Class D	62,500 - 250,000	Dominant sub-groups or equivalent	Class Ia, Class III with or without others
Class E	250,000 - 500,000	Dominang great groups or equivalent	"
Class F	>500,000	Dominant soil orders or equivalent	"

Table 3. Types of analyses in soil reports of LDCs.

AREAS OF SURVEY AND REFERENCE		MAP SCALE	AREA of SURVEY (km^2)	NO. PEDONS ANALYSED +	AVERAGE SAMPLE PEDON	TEXTURE		pH			EXCHANGE PROPERTIES					B.S. %	H* 1.2	KCl Al	C	M	BOD	Fr Fe
						INT	USDA	H_2O	KCl	OTHER	CEC	Ca	Mg	Na	K							
Bangladesh	(1)	126,000	3000	23(5)	4	X		X				X	X	X	X				X	X		
Thailand	(2)	100,000	4100	19(23)	5		X	X	X		X	X	X	X	X	X	X		X	X		
Malaysia	(3)	126,000	800	8(23)	5	X			X		X	X	X	X	X	X			X	X		
Philippines	(4)	200,000	13430	0/36																		
Sierra Leone	(5)	50,000	2590	14/16	3	X		X		X	X	X	X	X	X				X	X		
Lesotho	(6)	250,000	30344	(20)	3	X	X	X		X	X	X	X	X	X	X			X	X		
Usutu Basin, Swaziland	(7)	50,000	910	?	?	X		X	X	X	X	X	X	X	X	X			X	X		
Songhor Area, Kenya	(8)	50,000	526	(41)	7		X	X			X								X	X		
Antsohihy Madagascar	(9)	20,000	10000	(30)	3	X		X			X	X	X	X	X	X			X	X		

+Numerals in brackets give the number of mapping units in legend.

Types of Analyses

Table 1 lists most of the analyses employed and procedures are given in the manual on laboratory techniques (Soil Conservation Service, 1972). There is a trend in many countries to adopt most of these methods, perhaps because they have stood the test of time. However, there are local modificatons which one has to be aware of. The danger comes when the lab uses the name of an established method but a totally different procedure. For example, free iron is usually determined by the CBD method. There are reports where free iron is determined by: (a) Deb procedure, (b) a 6 N HCl extract, or (c) Ammonium oxalate - oxalic acid extraction in the dark, in the light, or with UV light. Each of these methods gives a different value. There is perhaps a need for adopting conventions regarding names of methods.

An Assessment of Published Soil Survey Reports

In Table 3, some information is given on a few soil survey reports of LDCs (randomly picked out, one from each country). A few have all class Ia analyses; some include other data, and a few have none. In some, profile descriptions are so vague that the analytical data become less meaningful. In one, the profile that was described is not the same as the one analyzed! In the same report the model profile was sampled in another locality. In many reports, the profile desctiption and analytical data are addendums to the report; reference to these are absent in the text.

The number of profiles analyzed bears no relationship to the mapping or taxonomic units. The number of horizons sampled is clearly a function of the training of the surveyor.

CONCLUSION

Despite the importance of soil analyses, in general the least attention is directed to them. There is a lack of appreciation of soil analyses and many soil surveyors of LDCs do not seem to be informed on the interpretation that could be made.

It will be useful and perhaps a valuable contribution if aid projects are directed to:

1. Training of laboratory personnel in analytical techniques.
2. Training of soil surveyors, especially soil survey assistants, on soil analyses and interpretation of data.

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E N T I S O L S[1/]

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I. INTRODUCTION

The Entisols are mineral soils with an AC profile set-up. They are extensive in the inter-tropical region and occupy about 20% of the earth's land area (Buol, et al., 1973). These soils show little or no evidence of development of pedogenic horizons. Horizons have not been formed because time has been too short. Some of these soils are steep and actively eroding, while others are on flood plains that frequently receive new deposit of alluvium. There are also some Entisols that are very old, the parent material of which is mainly quartz or other resistant minerals that do not alter to form horizons. However, buried horizons may be permitted if they are 50 cm or more deep. They do not have the combination of pergelic temperature regime and an aquic or peraquic moisture regime.

The Entisols in the Philippines are very recent river terrace deposits. They are the beach sand dunes and unweathered or very slightly weathered volcanic ash.

The mapped areas are La Paz, Legaspi, Quilado, Tamontaka, Tarug, Timnga, Titay, Villar, Zaragoza, Toran, Dadiangas, Gasan, Buguey, Palupandan, Luisita, Macolod, Magallanes, Magcalum, San Manuel, Sara, Silay, Sampangan, Sorsogon, Rugnan, Taal, Tupi, Libertad, Guimaras, Guinaoang, Ilagan, Lamut, Martalonga, Mayoyao, Mangalisan, Paete, Palitod, Paoay, Pasonanka, Poguis, Sabanga, and San Fabian series.

[1/] Paper presented at the XIV International Forum on Soil Taxonomy and Agrotechnology Transfer for the ASEAN region, June 16-28, 1986, held in the Philippines.

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The succeeding material is adopted from Soil Taxonomy, pages 197-209.

The Entisols are defined as mineral soils that meet requirement 3 and either 1 or 2.

1. They have sulfidic materials, within 50 cm of the mineral soil surface, or above a layer that is frozen about two months after the summer solstice, or have an n value of more than 0.7 and more than 8% clay in all subhorizons between 20 and 50 cm below the mineral surface and do not have a permafrost.
2. They do not have a diagnostic horizon, unless it is a buried horizon other than an ochric epipedon and anthropic epipedon, a histic epipedon consisting of organic materials, an albic horizon, a spodic horizon that has its upper boundary deeper than 2 m, or the amorphous material is not dominant in the exchange complex; and may have any of the following subject to the requirements stated:

* A salic horizon, except that, if the soil is saturated with water within 1 m of the surface for one month or more in some years and has not been irrigated, the upper boundary of the salic horizon must be 75 cm or more below the surface.

* If the soil is saturated with water within a m of the surface for 1 month or more when not frozen in any part, the sodium adsorption ratio (SAR) may exceed 13% (or sodium saturation, 15%) in more than half of the upper 50 cm only if SAR increases or remains constant with depth below 50 cm.

* A calcic or gypsic horizon or duripan if its upper boundary is more than 1 m below the surface (these presumed to be buried soil horizons or layers of geologic origin).

* If the texture is loamy fine sand or coarser to a depth of 1 m, plinthite may be present in the form of discrete nodules or disconnected soft red mottles if it constitutes less than half the volume in all subhorizons.

* Buried diagnostic horizons may be present if the surface of the buried soil is at a depth between 30 and 50 cm and the thickness of the buried soil is less than twice the thickness of the overlying deposits, or if the surface of the buried soil is deeper than 50 cm, or

* Ironestone at any depth.

3. If the soil temperature regime is mesic, isomesic, or warmer and if there are cracks in most years as wide as 1 cm at a depth of 50 cm when not irrigated, are Entisols if after the upper soil to a depth of 18 cm is mixed, have less than 30% or more clay in some subhorizon within a depth of 50 cm or do not have any of the following:

   * Gilgai;

   * At any depth between 25 cm and 1 m, wedge-shaped natural structural aggregates that have their long axes tilted 10° - 60° from the horizontal; or

   * At any depth between 25 cm and 1 m, slickensides close enough to intersect.

Different criteria are provided to separate the Entisols from all other orders.

1. The Entisols are distinguished from Alfisols by the absence of an argillic horizon, unless it is a buried horizon in the former.
2. The Entisols are distinguished from the Aridisols in not having the following:

 * A salic horizon if its upper boundary is within 75 cm of the surface and the soil is saturated with water within 1 m of the surface for one month or more at some time of the year;

 * A calcic or petrocalcic horizon, a gypsic or petrogypsic horizon or a duripan, if the upper boundary of any of them is within 1 m of the surface, unless it is a buried horizon; or

 * A cambic, argillic, or natric horizon, unless it is a buried horizon.

3. Entisols are distinguished from the Inceptisols by the following:

 * They have one of the following:
 1. An n value of more than 0.7 and at least 8% clay in all subhorizons between a depth of 20 and 50 cm below the mineral surface without permafrost; or
 2. **Sulfidic materials** within a depth of 50 cm below the mineral surface.

 * They do not have any of the following.
 1. A mollic, umbric, or plaggen epipedon;
 2. A histic epipedon consisting of minerals rather than organic soil materials;

3. A calcic or petrocalcic horizon or a duripan if the upper boundary of any of them is within 1 m of the soil surface, unless it is a buried horizon;
4. A cambic horizon;
5. A fragipan;
6. A sulfuric horizon that has its upper boundary within 50 cm of the mineral soil surface; or
7. Sodium saturation that is more than 15% in more than half of the upper 50 cm, unless the sodium saturation increases or remains constant with depth or unless the soil is not saturated with water within 1 m of the surface for as long as 1 month at a season when the soil is not frozen in any part.

4. Entisols are distinguished from Histosols by meeting the definition for mineral soils.
5. To distinguish Entisols from Oxisols, Entisols must not have a mollic epipedon.
6. To distinguish Entisols from Oxisols, Entisols must not have an oxic horizon and must not have plinthite that forms a continuous phase within 30 cm of the surface of the soil, if the soil is saturated with water at sometime of the year within that depth.
7. To distinguish Entisols from Spodosols, Entisols must not have a spodic horizon that has its upper boundary within 2 m of the surface of the soil.
8. To distinguish Entisols from Ultisols, Entisols must not have an argillic horizon, unless it is a buried soil horizon.
9. To distinguish Entisols from Vertisols, Entisols must have a frigid or colder temperature regime, or must meet one or both of the following requirements:

L 1

* Must not have cracks that are as wide as 1 cm at a depth of 50 cm in most years; or

* Either:

  1. After the surface soil to a depth of 18 cm is mixed, have $<$ 30% clay in some subhorizons above a depth of 150 cm; or

  2. Do not have gilgai, do not have a slickensides close enough to intersect, and do not have wedge shaped peds that have their long axes tilted 10° - 60° from the horizontal.

II. THE SUBORDERS

The Entisols have five suborders. They are the Aquents, Arents, Psamments, Fluvents, and Orthents.

The Aquents as the taxon "Aqu" indicate, are the Entisols that have aquic or peraquic soil moisture regime. They are continuously saturated with water, such as those in tidal marshes, in deltas or soils saturated at some time of the year.

The Arents are the Entisols that are deprived of horizons because they are deeply mixed by plowing, spading or movement of human activity. Unlike the other suborders, the Arents do not have great groups and typic subgroup.

The Psamments are the Entisols that have, at a certain depth, 35% by volume of rock fragments and have a loamy fine sand or coarser in all subhorizons. They are poorly graded (well sorted) sands of shifting or stabilized sand dunes. When dry and bare, they are subject to blowing and drifting and could hardly support wheeled vehicles.

The Fluvents are the Entisols that form in recent sediments deposited by water that have organic carbon content that decreases regularly with depth if the texture is homogenous. They can have any vegetation, any moisture regime, and they temperature regime, except pergelic. They are the alluvial soils in the 1938 classification.

The Orthents are the Entisols that do not have the diagnostic properties defining the other suborders. They are on recent erosional surfaces.

In the Philippines, most of the recognized Entisols belong to the suborder Psamments and Aquents

III. THE GREAT GROUPS

The 12 great groups of the order Entisols are summarized in Table 1. The number of great groups varies from one suborder to another while the numbers in the Table indicate their sequences in the key.

The general description of the great groups are as follows:

The "Sulf" great group is only in the suborder Aquents. They are recognized by the presence of sulfide materials within 50 cm of the mineral soil surface.

The "Hydr" great group is only in the suborder "Aqu". They have an n value of >0.7 and have at least 8% clay in all subhorizons between a certain depth. They must have a mean annual soil temperature >0°C.

The "Cry" great groups are in the suborder Aquent, Psamments, Fluvents, and Orthents. They are the cold wet soils of high mountains or tundra without permafrost or of cold coastal marshes. They are generally identified with a cryic soil temperature regime. The pergelic temperature is not permitted in the Aquents and Fluvents but allowed in the Psamments.

The "Fluv" great group is only in the suborder Aquents. They are commonly identified with a soil temperature regime warmer than cryic, an n value of 0.7 or less, or have a clay content are also required to firm up their identification.

Table 1. The great groups in Entisols

GREAT GROUP	S U B O R D E R S				
	AQUENTS	ARENTS	PSAMMENTS	FLUVENTS	ORTHENTS
Sulf	1				
Hydr	2				
Cry	3		1	1	1
Fluv	4				
Trop	5		5	5	4
Psamm	6				
Hapl	7				
Torr			2	4	2
Quartz			3		
Ud			4	6	5
Xer			6	2	3
Ust			7	3	6

The "Trop" great groups are in the Aquents, Psamments, Fluvents and Orthents. (The definition of the Tropaquents has not been tested and is provisional). They are commonly identified with an iso temperature regime. The Tropaquents, on the other hand, are the permanently warm and wet soils in depressions of intertropical regions, while the Tropopsamments have udic soil moisture regime (This classification is still provisional and incomplete).

The "Psamm" great group is only in the suborder Aquents. They are characterized with a sandy mixture and the water table is at or near the surface for long periods unless they are artificially drained.

tThe "Torr" great groups are in the suborder Psamments, Fluvents, and Orthents. They have arid climates and are identified with a torric soil moisture regime.

The "Quartz" great group is in the suborder Psamments. They are the freely drained quartz sand of humid to semiarid regions in mid or low latitudes. They are identified with a sand fraction that is 95% or more quartz, zircon, tourmaline, rutile, and other non-weatherable minerals.

The "Ud" great groups are in the suborders Psamments, Fluvents, and Orthents. They are commonly identified with a udic soil moisture regime and are usually found in humid regions in the middle latitudes.

The "Xer" great groups are in the suborders Psamments, Fluvents, and Orthents. They are commonly identified with a xeric soil moisture regime.

The "Ust" great groups are in the suborders Psamments, fluvents, and Orthents. They are recognized by their ustic soil moisture regime.

The mapped eEntisols in the Philippijns are placed in the "Trop" and "Fluv" great groups.

IV. THE SUBGROUPS

The subgroup name is formed by the great group name that is modified by one or more adjectives. There are 29 subgroup names provided in Entisols, but no subgroups have been provided for the great groups "Sulf" and "Cry". Their classification in Soil Taxonomy is provisional. On the other hand, suborder Arents have no great groups, but two subgroups are provided.

Most of the recognized Entisols in the Philippines are classified at the subgroup level as Aquic and Tropic. Limit between Entisols and Oxisols.

To distinguish Entisols from Oxisols, Entisols must no have an Oxic horizon and must not have Plinthite that forms a continuous phase within 30 cm of the surface of the soil if the soil is saturated with water at some time of the year within that depth.

Appendix A is the description and characterization of the Bugko series in teh Philippines which is classified as an Entisol. The soil is found in Samar province. It is a cogonal grassland with few coconuts that is derived from marine sands.

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BUGKO SERIES*

The Bugko series is a member of the mixed (?), isohyperthermic family of Aquic Tropopsammetns. They have a shallow solum but their effective soil depth is deep. They are moderately well drained. These soils have (very) dark grayish brown, grayish brown very dark brown and dark yellowish brown, friable to very friable sandy loam, and loamy sand A horizons no more than 30 40 cm thick with brownish mottles overlying C horizons composed of predominantly brownish (brown, yellowish brown, dark yellowish brown and brownish yellow) very friable to loose loamy fine sand and fine sand. Grayish mottles (gray, light gray, grayish brown and brownish gray) as well as brownish mottles (including strong brown) occur in the C horizons. The grayish mottles become more prominent with depth.

Bugko soils occupy positions on nearly level to gently sloping beach ridges of coastal plain landscapes

Typifying Pedon Bugko - cogon grassland with few coconut trees

(colors are for moist soil unless otherwise noted)

HORIZON	DEPTH (CM)	DESCRIPTION
Ap	0-20	Dark grayish brown (10YR 4/2) sandy loam: few medium distinct clear yellowish brown (10YR 5/8) mottles; fine granular structure; many fine and medium roots; clear smooth boundary.
C_1	20-30	Yellowish brown (10YR 5/4), loamy find sand; common medium prominent clear light gray to gray (10YR 6/1)mottles; fine granular structure; very few line roots; clear smooth boundary.

*Surveyed and classified by the Bureau of Soils in 1978.

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HORIZON	DEPTH	DESCRIPTION
C_2	30-150	Mottled dark yellowish brown (10YR 3/4) and light gray (10YR 6/1), loamy fine sand; common iron-manganese concretions.

Type Location

The type location is not the site for the typifying pedon described above. The type location is in Barrio Bugko, Municipality Mondragon, Northern Samar Prpvince, and was identified in 1952-1953 during the Reconnaissance Soil Survey of Samar Idland (Soil Report 42). The site for the typifying pedon is in Barrio Junction Municipality Laoang, Northern Samar, approximately 50 m to the north of the meeting point of the road from Catarman to Laoang and the road to Catubig.

Range in Characteristics

Solum thickness (that is in the case of Bugko series, only the thickness of the A horizon since there is no B horizon) ranges from 20-40 cm. However, effective soil depth is deep and the soils are free from gravel. Their mineralogy is assumed to be mixed on the basis that the soils probably contain less than 90 percent by weight of silica and other durable minerals that are resistant to weathering. The soils often have a content of organic carbon that decreases irregularly with depth or that remains relatively high in the C horizons. The soil temperature regime is isohyperthermic. Subsurface (C) horizons are wet for short but significant part of the year due to a seasonal high standing groundwater table. The soil are moist throughout their profiles for most of the year. Topsoils can be at or below wilting point for very short periods under rainfed conditions. The soils of Bugko series normally are not flooded by runoff or river water. Under exceptional conditions (typhoons) they can be partly flooded for short durations

A horizons are very dark grayish brown, dark grayish brown, grayish brown, very dark brown, dark brown and dark yellowish brown sandy loam,

loam and loamy sand few faint to distinct brownish mottles (mainly brown and yellowish brown). A horizons are normally 20-30 cm thick but may be as thick as 40 cm. Consistence is friable to very friable when moist, non-sticky to slightly sticky and non-plastic to slightly plastic when wet and soft to loose when dry. Structure is weak to moderate granular.

C horizons are mottled brownish and grayish. Brownish colors are dominant, at least in the upper portion of the C horizon, but grayish colors increase in prominence with depth. Brownish colors include yellowish brown, dark yellowish brown, brownish yellow, strong brown. Grayish colors include gray, light gray, grayish brown, light brownish gray. Textures include loamy fine sand and fine sand. Few to common small soft and hard-iron-manganese concretions may occur particularly in the lower C horizons. Consistence is very friable to loose when moist, non-sticky and non-plastic when wet.

Similar Series and their Differentiae

Bugko soils are somewhat similar to soils of Magsaysay series. Their main difference is in the internal soil drainage. Bugko soils are moderately well drained and are classified Aquic Tropopsamments whereas Magsaysay soils are well to somewhat excessively drained and are classified Typic Tropopsamments.

A fairly large number of other soils having characteristics and classification possibly similar to those of Bugko series, and that have been mapped in many parts of the country as yet are too loosely and inadequately defined and described for correlations with Bugko series. These soils might include: Angeles (Pampanga), Bacante (Central Luzon), Banga (Central Luzon), Barang (?) Bilad (?), Gasan (Marinduque), Guimaras (Iloilo), Irosin (Sorsogon), Kaunayan (Sulu), Laput (Central Luzon), Laylay (Marinduque), Luisita (Tarlac), Magcalon (Antique), Matulas (Cotabato), Pangasinan (Pangasinan), Patungan (Cavite), Pawing (Central Luzon), Pulupandan (Negros Occidental), Umingan (Pangasinan), and Villar (Zambales).

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Setting

Bugko soils occur on fairly well developed beach ridges on coastal plain landscapes. They are formed from marine sands. The beach ridges usually occur in positions more or less parallel to the coast line. Slopes are commonly less than 2 percent but in places slopes may be somewhat steeper up to 4 percent. The soil climate is characterized by a udic soil moisture regime and an isohyperthermic soil temperature regime.

Principal Associated Soils

Bugko soils series is primarily associated with soils of the Bugko, poorly drained, coarse loamy variant which occur is swales between the beach ridges of the Bugko soils. In a wider context, Bugko soil series is also associated with all other soils (and non-soils) occurring on coastal plain landscapes. These include Magsaysay series, Bongliw, moderately well drained variant and Obando series on beach ridges and beach ridge remnants as well as Bugko, poorly drained, fine loamy variant, Bongliw series and Bongliw somewhat poorly drained variant on former tidal flats. All these soils have internal soil drainage ranging from well to somewhat excessively drained for Magsyasy soils to poorly drained for soils of the Bugko variants. Bugko soils are also loosely associated with the saline soils of active tidal flats and non-soil areas of beaches and dunes.

Drainage and Permeability

Bugko soils are moderately well drained. Ground water tables presumably fluctuate between 60 to 200 cm from the soil surface. Permeability is estimated to be rapid. Infiltration rates are thought to be moderate to rapid.

Use and Vegetation

Bugko soils are mainly covered by cogon grass and related vegetation. Thus, they provide rangeland for some rough grazing and browsing. Minor parts are planted with coconut trees and some upland crops. There are also settlements.

Distribution and Extent

Bugko soils have been described to occur on major coastal plains of North and East Samar. The series has a small extent (less than 40 sqm).

Series Established

The series was first described in the course of the reconnaissance soil survey of Samar province during 1952 and 1953 by A. Simon and party. The series was redefined and its concept considerably narrowed* during the detailed soil survey of areas in North and East Samar in 1977. However, the status of the series is still tentative and more information is needed for further precision of the series concept.

Remarks

The Bugko soils have been classified Aquic Tropopsamments on the basis of their sandy particles size class which excludes the recognition of a cambic horizon. Therefore, the horizons below the A horizon have been designated as C horizon although they show some evidence of alteration in the form of color with stronger chroma and presence of mottles.

According to the USDA 1938 soil classification, the Bugko soil series would find placement in the Regosols Great Group.

Following the UNESCO/FAO Soil Map of the World Legend, Bugko series pertain to Dystric Regosols.

*The original concept of Bugko series as described by A. Simon et al., in soil report 42 included the range of characteristics pertinent to soils of Bugko series and Bugko, poorly drained, coarse loamy variant.

SOIL PROFILE CHEMICAL AND PHYSICAL ANALYSIS DATA
AREA: CATUBIG, NORTH SAMAR

LOCATION: Barrio Junction
AIRPJOTO/OBS. NO.: FL 34-2

SOIL SERIES: Bugko
FINAL MAP SHEET NO.

LAB. NO.	HORIZON	DEPTH (cm)	LIME TEST	pH H_2O 1:1	pH $CaCl_2$ 1:2	O.C. (%)	O.M. (%)	AVAILABLE P (ppm)	EXTRACTABLE K (ppm)	FREE Fe_2O_3 (%)
6262	Ap	0-20		5.1	4.7	1.3	2.3	6.4		
6263	C1	20-30		5.7	5.4	0.04	0.06	10.3		
6264	C2	30-150		5.7	4.9	0.3	0.5	4.0		

HORIZON	DEPTH (CM)	MILLIEQUIVALENTS PER 100 g SOIL — EXCHANGEABLE BASES Ca+Mg	Na	K	SUM	EXCH. ACIDITY	C.E.C. (SUM)	BASE SATURATION (%)	Zn (ppm)	EXCH. Al (ppm)
Ap	0-20	3.4	0.1	0.4	3.9	13.1	17.0	23		
C1	20-30	2.7	0.1	0.2	3.0	3.2	6.2	48		
C2	30-150	2.7	0.1	0.2	3.0	3.9	6.9	43		

HORIZON	DEPTH (CM)	PARTICLE SIZE DISTRIBUTION — TOTAL SAND (%)	SILT (%)	CLAY (%)	TEXTURE CLASS	SETTLING VOLUME (ml)	$CaCO_3$ (%)	ELECTRICAL CONDUCTIVITY (mmho/c.) 1:1	PASTE
Ap	0-20	96	0	4	18			0:4	
C1	20-30	95	0	5	S			0:1	
C2	30-150	94	0	6	S			0:1	

INCEPTISOLS[1/]

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INTRODUCTION:

Inceptisols occur in a wide range of latitudes having subhumid to humid climates on old, as well as on young surfaces where the precipitation exceeds potential evapotranspiration every month. In areas where evapotranspiration exceeds precipitation at some time of the year, Inceptisols are restricted to post-pleistocene surfaces. Those on old surfaces develop where cold temperature slow down the decomposition of minerals, thus inhibiting the rapid process of soil development; while those on young surfaces, such as the recently accumulated alluvial deposits, form fast enough to develop clear pedogenic horizons.

Some important features of areas where Inceptisols occur include a highly resistant parent material, abundance of volcanic ash, steep lands and depressions, and young geomorphic surfaces where soil development is limited (Buol, et al., 1973).

Inceptisols are permitted to have many kinds of diagnostic horizons but not an argillic, epodic, oxic, gypsic, petrogypsic, salic, shallow plinthite, and natric horizons. They may have any kind of epipedon although the mollic epipedon is rare. Commonly they have an ochric epipedon over a cambic horizon with or without any underlying fragipan, or an umbric epipedon overlying a duripan or fragipan. They are the only soils having a plaggen epipedon.

In the Philippines, the Inceptisols are dominantly devoted to agricultural production. In fact, most of the wetland rice areas belong to this soil category. They are mapped as Camansa, Calumpang, see complete list in Appendix C.

1/ Paper presented at the XIV International Forum on Soil Taxonomy and Agrotechnology Transfer for the ASEAN region, June 16-28, 1986 held in the Philippines.

ATTRIBUTES OF THE ORDER

The unique properties of the Inceptisols are the altered horizons that have no illuvial horizon, enriched either with silicate that contain aluminum or with an amorphous mixtures of aluminum and organic carbon. The clay fraction has moderate to high cation retention capacity. They contain an appreciable amount of weatherable minerals and have a soil texture finer than loamy sand.

The complete definition of the Inceptisols may be found in Soil Taxonomy (1975), pages 227-228 and the succeeding discussions is adopted from these pages.

LIMITS BETWEEN SOME OTHER ORDERS

Inceptisols are distinguished from Alfisols by the absence of an argillic or natric horizon, unless it is a buried soil horizon, or the absence of a fragipan that has 1 mm thick of clay skins in some part.

They are distinguished from the Entisols in having an Exchange Complex Dominated by Amorphous Materials (ECDAM), or an n value of 0.7 or less, or less than 8% clay. They must not have any sulfidic materials within 50 cm of the mineral soil surface and must have one or more of the permissible diagnostic horizons.

SUBORDERS

The Inceptisols have six suborders, although the Andepts are proposed to be elevated to the order category as Andisols.

The Aquepts are Inceptisols that are identified with their characteristic wetness: the Andepts for their low bulk density or their high contents of virtic volcanic ash, cinders or other pyroclastic materials; the Plaggepts for their plaggen epipedon: the Tropepts for their warm humid temperature regime; and the Ochrepts for their ochric epipedon or an umbric or mollic epipedon of less tha 25 cm thick and a mesic or warmer soil temperature regime.

All others that do not meet the above characteristics are the Umbrepts. The classification of the plaggepts, however, has not been developed because they do not occur in the U.S.A.

The majority of the Inceptisols in the Philippines belong to the suborder Aquepts and Tropepts.

THE GREAT GROUPS

The Inceptisols are provided with 18 great groups (Table 1). Here, the numbers indicate the sequence of their placement in the key to the great groups.

The "Frag" great groups have a brittle pan in the subsurface which are management limitations in the "Aqu", "Ochr", and "Umbr" subgroups.

The pan in the "Dur" great groups is usually massive and interferes with ghe development of most roots and water movement although it is relatively not strongly indurated as those in the other orders.

Table 1. The Great Groups in Inceptisols

GREAT GROUPS	SUBORDERS					
	AQU	AND	PLAGG	TROP	OCHR	UMBER
Frag	4				1	1
Dur		2			2	
Cry	5	1			3	2
Ust				3	4	
Xer					5	3
Hydr		3				
Plac	2	4				
Eutr		6		4	6	
Dystr		7		5	7	
Virt		5				
Sulf	1					
Hala	3					
Plinth	6					
And	7					
Huma	9			1		
Trop	8					
Sombr				2		
Hapl	10					4

The "Cry" great groups are in the suborders "Aqu", "And". "Ochr" and "Umbr". They are the soils having cryic or pergelic soil temperature regime

The "Ust" great groups are in the suborders "Trop" and "Ochr". They are recognized by their ustic moisture regime and a base saturation of 50% or more at certain depths.

The "Xer" great groups are in the "Ochr", and in the "Umbr" suborders. They are identified with a xeric soil moisture regime.

The "Hydr" great groups are only in the suborder "And". They are associated with a very high, well-distributed rainfall, and a perudic soil moisture regime.

The "Plac" great groups are only in the suborders "Aqu" and "And". They are identified with a placic horizon which is normally located within 25-50 cm of the mineral soil surface. They are associated with very humid climates and evenly distributed rainfall throughout the year or with no dry season.

The "Eutr" great groups are in the suborders "And", "Trop", and "Ochr". They have a base saturation $>$ 50% in some or in all subhorizons. The Eutrochrepts, however, must have $\geq$ 60% base saturation because their parent material is usually calcareous.

The "Dyster" great groups are in the same suborders as those in the "Eutr" great groups. They are identified with a base saturation $<$50% or $<$60% in the case of the "Ochr" suborders.

The "Vitr" great groups are only in the suborder "And". They are associated with areas with a 15-bar water retention $<$20% in the fine earth fraction of the whole soil at certain days.

The "Sulf" great groups are only in the "Aqu" great groups. They are the acid sulfate soils which are usually found in drained .

coastal marshes near the mouths of rivers that are almost free of carbonates. Their classification has not been fully developed.

The "Hala" great group is only in the "Aqu" suborder. This consists of soils with a shallow ground water wherein capillary rise and evapotranspiration result in the deposits of sodium or other salts in the surface. They are the sodic or saline soils that are identified with $\geq$ 13 sodium adsorption ratio (SAR) or sodium saturated of $\geq$ 15%.

The "Plinth" great group is only in the "Aqu" suborder. It is identified with a plinthite that forms a continuous phase or constitute more than half the matrix within some subhorizon at 30 cm-125 cm of the soil surface.

The "And" great group is only in the "Aqu" suborder. It has an SAR $<$ 13 or $<$ 15% sodium saturation with a bulk density of $<$ 0.85 g/cm^3 (at 1/3-bar water retention) of the fine earth fraction and an exchange complex dominated by amorphous materials.

The "Hum" great groups are in the suborders "Aqu" and "Trop". They have an umbric, a mollic, or a histic epipedon in the "Aqu" suborder or a base saturation 50% but have $\geq$ 12 kg organic carbon in the "Trop" suborder.

The "Trop" great group is only in the suborder "Aqu". It has an isomesic or warmer iso temperature regime but the soil temperature regime is not a constraint to soil use.

The "Sombr" great group is only in the suborder "Trop". It is recognized by the presence of a sombric horizon. The classification of the soil has not been fully developed.

The "Hapl" great groups are in the suborder "Aqu" and "Umbr". They are the soils that do not have the diagnostic properties of the other great groups.

Most of the upland Inceptisols in the Philippines are placed in the "Eutr" and "Dystr" great groups.

THE SUBGROUPS

Following the great group in the key is the subgroup category. Here, the subgroup name consists of the great group name that is modified by one or more adjectives which indicate that they are integrades or extragrades.

The intergrades have properties of their great groups including some properties of another taxon, while the extragrades indicates the nature of the aberrant properties.

The number of subgroups of the order Inceptisols is too many to permit a detailed discussion of each. There are 40 subgroups, excluding those having multiple subgroup names.

The wetland rice areas in the Philippines are either placed in the Aquic or Aeric subgroups.

Appendix A is the Obando series of the Philippines which is placed in Soil Taxonomy as coarse loamy over sandy, mixed, isohyperthermic Typic Eutropepts. It is a wetland soil devoted to paddy rice. The range in characteristics, similar soils and their differentiae, associated soils, setting, etc. are described and characterized by the Bureau of Soils (1977).

OBANDO SERIES

The Obando series is a tentative member of the coarse loamy over sandy, mixed, isohyperthermic family of Typic Eutropepts. They are deep and well to moderately well drained. These soils have dark yellowish brown, dark brown, brown, yellowish brown, dark grayish brown and grayish brown, friable loam, fine sandy loam, silt loam and sandy clay loam A horizons no more than 30 cm thick with distinct yellowish brown and strong brown mottles, overlying B horizons that are composed of brown, dark brown, yellowish brown, dark yellowish brown fine sandy loam over loamy fine sand and fine sand with, or without, few faint brownish mottles. C horizons below 50-120 cm from the soil surface are mainly dark grayish brown, grayish brown, dark gray, gray and olive gray faintly to distinctly mottled loamy fine sand and fine sand deposits that may include sandy loam and silt loam layers. C horizons may include marine shell fragments.

Obando series soils are formed on nearly level, weakly developed beach ridges and beach ridge remnants on coastal plain landscapes.

Typifying Pedon   Obando loam - paddy rice field (colors are for moist soil).

HORIZONS	DEPTH (CM)	DESCRIPTION
Ap	0-18	Grayish brown (10YR 5/2) loam; common fine distinct clear strong brown mottles; moderately strong medium parting to fine angular blocky structure; friable when moist; nonsticky and non-plastic when wet; few fine continuous vertical and oblique tubular simple and open pores; many fine roots; clear smooth boundary; pH 5.4.
B_2	18-40	Yellowish brown (10YR 5/6); very fine sandy loam; few fine faint diffuse brown to dark brown mottles; moderately strong medium angular

HORIZONS	DEPTH (CM)	DESCRIPTION
		parting to fine subangular blocky; friable when moist; continuous vertical and oblique exped tubular open pores; few small soft black manganese concretions; few fine roots; diffuse smooth boundary; pH 6.8.
B_3	49-85	Brown to dark brown (10YR 4/3) very fine faint diffuse dark yellowish brown mottles; weak medium subangular blocky structure; friable when moist; non-sticky and non-plastic when wet; common fine continuous vertical and oblique exped tubular simple open pores· very few small gravels; few fine roots; abrupt smooth boundary; pH 7.0.
C_1	85-108	Dark grayish brown (10YR 4/2) loamy very fine sand; few fine faint diffuse brown to dark brown mottles; very friable when moist; non-sticky and non-plastic when wet; very few fine continuous random exped tubular pores; few (15 percent by volume) small white marine shells; few fine roots; clear smooth boundary. pH 7.2.
C_{2g}	108-150	Dark gray (N 4/1) loamy fine sand; few fine distinct clear olive brown and grayish brown mottles; friable when moist; non-sticky and non-plastic when wet; fine continuous random exped tubular simple open pores; many (50-65 percent by volume) small white marine shells; few fine roots; pH 7.8.
C_{3g}	150-260	Very dark gray (N 4/) wet fine sand; few fine distinct clear olive brown mottles; non-sticky and non-plastic; many (50-65 percent by volume) small white marine shells; pH 8.2.

Type Location

The type location is not the site for the typifying pedon described above. The type location is in the coastal strip between Obando and Polo in Bulacan Province. The site for the typifying pedon, however,, is very close and is located in Balancas, Valenzuela, Bulacan province; coordinates 14° 42' 49" N and 120° 56' 19" E.

Range in Characteristics

Solum thickness (that is the combined thickness of A and B horizons) ranges from 50-120 cm. Effective soil depth is deep and the soils are virtually free from gravel and stones, although a few gravels may occur in the lower B and C horizons. Their mineralogy is assumed to be mixed in the determinant size fraction (0.02 - 2 mm_ since this fraction seems to contain less than 90 percent by weight of silica minerals and other extremely durable minerals that are resistant to weathering. The soil temperature regime is isohyperthermic. Soils are moist for the greater part of the year with short to very short periods when topsoils can be at or below wilting point dependen- on the local climatic regime. They are level position and runoff from adjacent higher and more sloping areas. In places, water is artificially impounded on the soil surface for rainfed (paddy) rice cultivation.

A horizons are dark yellowish, dark brown, and brown when cultivated to upland and/or tree crops but matrix colors are dark grayish brown and grayish brown when cultivation to rice under submerged conditions. A horizons have common and distinct yellowish brown and strong brown mottles. Textures may range from loam to sandy loam, sandy clay loam and silt loam. A horizons are between 20 and 30 cm thick. Consistence is friable when moist and non-sticky to slightly sticky and non-plastic to slightly plastic when wet. Structure is moderate to strong blocky.

B horizons are brown, dark brown, yellowish brown and dark yellowish brown with or without, faint diffuse brownish mottles.

Textures in the upper B horizon are coarse loamy (fine sandy loam) and change to sandy (loamy fine sand and fine sand) in the lower B horizon. Structure is moderate to strong blocky in the lower B horizon. Consequently, the B horizon includes a cambic horizon which, however, is restricted to the coarse loamy upper part of the B horizon that had well developed blocky structure. Organic carbon contents regularly decrease with depth and reaches a level below 0.2 percent in the lower B horizon. Moist consistence is non-sticky and non-plastic. Few small soft and slightly hard black manganese concretions may occur. Likewise, few to very few gravels may be present in the lower B horizon.

C horizons below 50-120 cm from the soil surface are dark grayish brown, grayish brown, dark gray, gray, olive gray and even very dark sandy deposits (loamy fine sand and fine sand) that may include also more loamy layers of fine sandy loam and silt loam. Few, faint to distinct, diffuse to clear, brownish mottles may be present. Usually, there are common to many (more than 15 percent by volume) marine shell fragments that increase in abundance with depth*. Consistence is loose to very friable when moist and non-sticky, non-plastic when wet.

Similar Soils and their Differentiae

Bongliw, moderately well drained variant soils are somewhat similar to Obando soils in that they are also classified Eutropepts at the great group level of classification and in that they also occur on beach ridge remnants on coastal plain landscapes. Bongliw, moderately well drained variant soils are different in their internal soil drainage class (moderately well drained), their irregular organic carbon content, and their particle size class (fine). Hence, they, are classified, fine Fluvaquentic Eutropepts.

In the Samar and Bukidnon provinces and in the Penaranda River Basin area, a number of other soils have been identified and mapped that

*The presence of marine shell fragments is not diagnostic for the series since they commonly occur below the control section (25-100 cm from the soil surface) of the Obando soils.

that are also classified Eutropepts at the great group level of classification. These soils have been commonly formed on alluvial plain landscapes. They are Catubig series (fine Fluvaquentic Eutropepts) on leavees on Samar Island; Agustin series (fine loamy over sandy Fluventic Eutropepts), Penaranda series (fine loamy over sandy-skeletal Fluventic Eutropepts on flood plains in Bukidnon province and the Penaranda river basin area; Nabago series (fine Fluvaquentic Eutropepts) on the alluvial terraces in Bukidnon province.

Apart from the above soil series and variant there are other soils that have been mapped during surveys in the past in various parts of the country that could have characteristics similar to soils of the Eutropepts great group. These soils, however, have been described insufficiently detailed to enable proper identification, classification and correlation, and therefore, their status remains uncertain. They include the following soils (with their province or area of origin between parenthesis): Bauyan (New Lanao del Norte), Dagani (Cotabato), Donsol (Sorsogon), Kapalangan (Penaranda River Basin Area), Indan (Camarines Norte), Makatok (Oriental Mindoro), Santa Rita (Iloilo), Siaton (Negros Oriental), and Zaragoza (Penaranda).

Setting

Obando soils have been defined to occupy positions on nearly level (0-2 percent slopes), weakly developed beach ridges and beach ridge remnants on coastal plain landscapes. They consist of Fluviomarine deposits that are sandy or coarse loamy in composition. Soil climate is characterized by a udic soil moisture regime and an isohyperthermic soil temperature regime.

Principal Associated Soils

In Bulacan province where Obando soils were first described and mapped, they are associated with "Matimbo" soils. In the report on the "Semi-detailed Soil Survey of Pampanga Delta Development

Project" by Alfonso E. Crucena prepared in 1975 the "Matimbo" soils are characterized as somewhat poorly drained and fine clayey.

In Eastern Samar province where Obando soils are recognized during the detailed survey of the coastal and alluvial plains around Dolores, Ca-Avid and Oras, they are associated with other soils on the coastal plain landscapes, i.e., soils of Bugko series, Bugko poorly drained, fine loamy variant, Bongliw somewhat poorly drained variant.

Drainage and Permeability

The Obando soils are well to moderately well drained. The hydraulic conductivity is moderately rapid to rapid and basic infiltration rates are estimated to be slow to moderate under wetland rice conditions and moderates to rapid under upland/tree cropping conditions. These soils are subject to fairly frequent shallow flooding of short durations by rain and runoff water.

Use and Vegetation

In Bulacan province, Obando soils are commonly planted to paddy rice during wet seasons. Parts are grown to vegetables (tomatoes, eggplants, string beans. mungo, squash and other leafy vegetables) during dry season with irrigation water.

In Eastern Samar, main forms of land use are rainfed rice cultivation following the "payatac system" and coconut production. The payatac system of rice cultivation is characterized by a simple form of land preparation (carabao feet trampling) and the absence of water and weed control through bunding and impounding of water on the soil surface. Rice yields under the payatac system are low. During fallow periods "payatac" fields are used as rough carabao pasture.

Distribution and Extent

Obando soils have been reported to occur in Bulacan province, Luzon and Eastern Samar province, Eastern Visayas. Their total extent is still small and is estimated to be far less than 40 sqm.

Series Established

The series was first described during the reconnaissance "Soil Survey of Bulacan Province" carried on by M.M. Alicante et al., in 1939 (Soil Report No. 1, Bureau of Soils). Later, in 1975, the soils were described in much more detail during the course of the "Semi-detailed Soil Survey of Pampanga Delta Development Project" by A.E. Cruzena et al., The soils were again reported in 1977 during the field work of the detailed survey on the coastal and alluvial plains of Dolores, Can-Avid and Oras, Eastern Samar. The status of the series is still tentative since much more information (detailed profile description and analysis) is needed to further specify the range of characteristics, to check on the classification and the extent of the series.

Remarks

Much more information is needed to test the tentative classification of Obando soils.

According to the USDA 1938 Soil Classification System the Obando series would probably be placed in the Gray Brown Podzolic soils great group.

Following the UNESCO/FAO Soil Map of the World Legend, Obando soils pertain to Eutric Cambisols.

Mailag series in Appendix B represents the Aeric Tropaquepts in the Philippines. It was described and characterized by the Bureau of Soils in 1977.

SOIL PROFILE CHEMICAL AND PHYSICAL ANALYSIS DATA
AREA : PAMPANGA, DELTA

SOIL SERIES: Obando
FINAL MAP SHEET NO.:

LOCATION: Balancas, Valenzuela, Bulacan Province
AIRPHOTO/OBS. NO.:

LABORATORY NO.	HORIZON	DEPTH (CM)	LIME TEST	pH H_2O 1:1	pH $CaCl_2$ 1:2	O.C. (%)	O.M. (%)	AVAILABLE P (ppm)	EXTRACTABLE K (ppm)	FREE Fe_2O_3 (%)
CP67	Ap	0-18		5.6	4.3	0.52	0.89	Trace	104	1.4
68	B_2	18-40		7.4	[illegible].6	0.14	0.24	3	200	1.9
69	B_3	40-85		7.8	6.2	0.05	0.09	Trace	135	0.8
70	C_1	85-108		7.9	6.1	0.08	0.14	3	424	0.3
71	C_{2g}	108-150		8.4	7.0	0.04	0.06	4	1200	0.2
72	C_{3g}	150-260		8.7	6.9	0.08	0.14	6	768	0.4

HORIZON	DEPTH (CM)	MILLIEQUIVALENTS PER 100 g SOIL: EXCHANGEABLE BASES Ca+Mg	Na	K	SUM	EXCH. ACIDITY	C.E.C. (SUM)	BASE SATURATION (%)	Zn (ppm)	EXCH. Al (ppm)
Ap	0-18	8.6	0.2	0.0	8.8	3.4	12.2	72		
B_2	18-40	13.8	0.3	0.1	14.2	1.4	15.6	92		
B_3	40-85	19.0	0.6	0.1	19.7	1.0	20.7	95		
C_1	85-108	11.1	1.0	0.1	12.2	1.9	14.1	87		
D_{2g}	108-150	14.6	1.1	0.2	15.9	Trace	15.9	99		
C_{3g}	150-260	13.5	1.3	0.5	15.3	Trace	15.3	99		

HORIZON	DEPTH (cm)	PARTICLE SIZE DISTRIBUTION: TOTAL SAND	SILT (%)	CLAY (%)	TEXTURE CLASS	SETTLING VOLUME	$CaCO_3$ (%)	ELECTRICAL CONDUCTIVITY (mmho/cm) 1:1	PASTE
Ap	0-18	60.0	20.4	19.6	SL/SCL		0.6		
B_2	18-40	70.6	12.6	16.8	SL		1.0		
B_3	40-85	85.7	5.7	8.6	LS		1.8		
C_1	85-108	92.2	1.0	6.8	S		1.7		
C_{2g}	108-150	92.6	0.6	6.8	S		1.8		
C_{3g}	150-260	34.6	58.6	6.8	Sil		1.5		

APPENDIX B

MAILAG SERIES

The Mailag series is a member of the fine, mixed, non-acid, isohyperthermic family of Aeric Tropaquepts. They are deep and somewhat poorly drained. The soils have (very) dark gray and (very) dark grayish brown, friable to firm silty clay loam, clay loam or clay A horizons no more than 50 cm. thick that have yellowish brown and strong brown mottles and variable quantities of iron-manganese concretions, overlying cambic B horizons composed of gray and brown mottles, friable to firm clay loam, silty clay and clay also containing variable quantities of iron-manganese concretions as well as small rock fragments. C horizons below 100-150 cm have colors and textures similar to those of the cambic B horizons but have no or very weakly developed structure. Mailag soils are formed on nearly level to gently sloping alluvial terraces and fans of young volcanic origin that occur at the base of the young volcanic landscape.

<u>Typifying Pedon</u> Mailag silty clay loam - paddy rice (color are for moist soil unless otherwise noted).

HORIZON	DEPTH (CM)	DESCRIPTION
Ap	0-17	Very dark grayish brown (10YR 3/2) silty clay loam; few fine faint brown to dark brown (7.5 YR 4/2) mottles; non-sticky, non-plastic when wet; few horizontal root channels; many fine to medium roots; clear smooth boundary.
A_{3cn}	17-26	Dark grayish brown (10YR 4/2), gravelly clay loam; few fine faint diffuse strong brown (7.5YR 5/6) mottles; moderate fine and medium angular and subangular blocky structure; slightly firm when moist; slightly sticky and slightly plastic when wet; few fine and medium

HORIZON	DEPTH (CM)	DESCRIPTION
		tubular pores; gravel consisting of many (40% by volume) fine soft and hard spherical and irregular black Mn concretions; very few fine roots.
B_{1gcn}	26-41	Mottled gray (10YR 5/1) and yellowish brown (10YR 5/4), gravelly clay loamy moderate medium and coarse angular and subangular blocky structure; slightly firm when moist; slightly sticky and slightly plastic when wet; gravel consisting of many (30% by volume) fine soft and hard spherical and irregular black Mn concretions and few fine rock fragments; no pores.
B_{2g}	41-69	Light gray to gray (10YR 6/1), silty clay loam; few fine distinct clear strong brown (7.5YR 5/8) mottles; moderate fine and medium prismatic and angular blocky structure; slightly firm when moist; slightly sticky and slightly plastic when wet; few fine soft and hard spherical black Mn and brown Fe concretions.
B_{3g}	69-110	Light gray (10YR 7/1) wet, silty clay loam; common fine to medium prominent clear yellowish brown (10YR 5/6) mottles; moderately strong, medium to coarse columnar parting to subangular slightly sticky and slightly plastic when wet; few fine and medium tubular pores; few soft black Mn concretions; common hard volcanic rock fragments; below 110 cm hard rock fragments.

Type Location

The type location is the site for the typifying pedon as described above. It is approximately 1,200 m west of the church of Barrio Mailag, Valencia, Bukidnon, Mindanao.

Range in Characteristics

Solum thickness (that is the combined thickness of the A and B horizons) ranges from 100-150 cm. The soils are deep but contain variable quantities of gravel which usually make up less than 35% by volume of the soil mass but that may be more than 35% by volume in minor parts of the solum. Gravel consists of fine (2-5 mm diameter), soft and hard black Mn concretions and some brown Fe concretions as well as some fine rock fragments. In places, surface stones and boulders may occur but they occupy less than 2-3% of the surface. In the absence of clay mineralogy data, their mineralogy is described to be mixed (?) on the basis of CEC figures (CEC by sum 30-50 meq/100 g). The soil temperature regime is isohyperthermic. Soils are moist (or wet) for the greater part of the year with short to very short periods when bare topsoils can be at or below wilting point. They are liable to slight flooding caused by over-flow of creeks.

A horizons are very dark gray, dark gray, very dark grayish brown and dark grayish brown with occassional dark reddish gray colors. Textures include non-gravelly or slightly gravelly and gravelly clay loam, sandy clay loam, sandy clay, clay and silty clay loam. The A horizons are 20-50 cm thick. Consistence is friable to firm when moist and slightly sticky, slightly plastic when wet. Structure is massive to weak blocky.

Cambic B horizons extend down to 100-150 cm from the soil surface and are mottled gray and brown clay loam, silty clay loam, clay and silty clay with few to many gravels. In some subhorizons of the cambic B horizons grayish colors may predominate; in other subhorizons the brownish colors may be dominant. The grayish colors may include dark gray, gray, light gray, dark grayish brown and light brownish gray. Brownish colors are dark yellowish brown, yellowish brown, dark brown, brown and strong brown. There is no or only slight evidence of clay translocation into the B horizons. Structure is moderate prismatic parting to blocky. Consistence is slightly firm to firm when moist and slightly sticky or sticky, slightly plastic or plastic when wet.

C horizons have colors, textures and consistence that are similar to those of the B horizons. Colors may include reddish gray and textures may also be sandy clay loam or sandy clay. Structure is weak to absent with depth and B horizons change gradually to C horizons.

Similar Series and their Differentiae

Mailag series is similar to Maramag series which occurs in the same setting on alluvial terraces and fans of young volcanic origin. Maramag soils are more acid and have lower pH values throughout their profiles. This is expressed in the classification of Mailag and Maramag series.

- Mailag series: non-acid class at the family level of Aeric Tropaquepts.
- Maramag series: acid class at the family level of Aeric Tropaquepts.

IN addition, Maramag soils do not contain gravel of Mn-Fe concretions and rock fragments.

Mailag series are also similar to other somewhat poorly drained alluvial soils that, however, occur in different settings. Cagugubngan series occurs on alluvial flats offloodplains on Samar Island and is also non-acid. Tagulod andRamos series make up part of the alluvial river landscape which is genetically different from the alluvial landscape that is associated with Cagugubngan series. Tagulod and Ramos series occupy positions on low terraces above river floodplains. Both series are classified Aeric Tropaquepts. Tagulod series has fine and Ramos coarse loamy particle size class. Bengliw, somewhat poorly drained variant (that has been proposed as Laoang series) on Samar

Island occurs on former tidal flats of coastal plain landscapes. Several other series in the country are classified Typic Tropaquepts. These poorly drained soils occur on floodplains (Sadugsuron series), terraces (Laligan, Maapag series) and coastal plains (Bongliw series).

Numerous other soils having characteristics presumably similar to those of Mailag series that have been mapped in many parts of the country, as yet, are too loosely and inadequately defined and described for correlation with Mailag series. Such soils are listed in the description of Maramag series and therefore, reference is made to that description.

Setting

Mailag soils occur on nearly level to gently sloping (0-5%) alluvial terraces and fans of young volcanic origin that occupy positions at the base of the "young volcanic landscape" in Bukidnon province. Their parent materials are derived from the basic volcanic rocks (mainly basaltic) that compose the "young volcanic landscape". Soil climate is characterized by an aquic soil moisture regime and an isohyperthermic soil temperature regime. Surface stones and boulders may occur locally but they occupy less than 2-3% of the surface. Mailag soils are susceptible to slight or moderate erosion.

Principal Associated Soils

Mailag soils are directly associated with Maramag and Bancud soils on the same terraces and fans of young volcanic origin that form the setting for Mailag soils Maramag soils differ in that they are more acid (acid class at family level) and that they do not contain gravel of Fe-Mn concretions and rock fragments. Bancud soils occupy positions on levees on the terraces and fans and are classified Typic Dystropepts.

In a wider setting, Mailag soils are associated with Adtuyon soils to the "young volcanic landscape". Adtuyon soils are classified Oxic Dystropepts.

Drainage and Permeability

The Mailag soils are somewhat poorly drained. Groundwater tables of seepage water fluctuate between 50 to 200 cm from the soil surface. Permeability is estimated moderate to moderately rapid. The basic infiltration rates are very slow to slow under wetland rice conditions and moderately rapid to rapid under upland crops. Surface runoff is very slow to moderate dependent on slope and land use. The soils are subject to slight flooding by creek overflow. When grown to wetland rice surface water is impounded.

Use and Vegetation

Main land uses are cultivation of paddy rice and corn. Usually two crops can be grown per year. Surface stones and boulders occur locally and then may hamper mechanical tillage. Susceptibility to slight or moderate erosion presents another hazard to cultivation.

Distribution and Extent

Mailag series has been described to occur in the Pulangi basin of Bukidnon province. Their extent is small and is less than 40 sqm.

Series Established

The series are proposed and described in a general form during the soil survey of Bukidnon province, Philippines (Soil Report 21), pp 25-26 by J.A. Mariano and party in 1955. The soil was described again with more precision during the "Semi-detailed Soil Survey and Land Classification of the Pulangi Irrigation Project. Valencia Maramag and Quezon, Bukidnon" by C.B. Alcalde and C.Q. Tingson in 1974, pp. 30-32. Its current concept was further refined and established during the "Detailed Survey of the Pulangi 3 Project Area, Valencia, Bukidnon" during 1976 by Bureau of Soils and UNDP/FAO. This soil series description is the first comprehensive and detailed description of the series. However, its status remains tentative until more data are gathered.

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Remarks

According to the USDA 1930 soil classification system the Mailag series would be placed in the low Humic Clay Soils great group.

Following the UNESCO/FAO Soil Map of the World Legend, Mailag soils pertain to Dystric Gleysols.

The term "young volcanic" as used in this series description is essentially a physiographic term. It is used in Bukidnon province to distinguish the "Young Volcanic Landscape" and its parent material (Pliocene-Quarternary, mainly basaltic, lava flows and pyroclastics) from the "Old Volcanic Landscape" which are of Oligocene-Lower Miocene age and which consists of volcanic agglomerates and andesitic formations. The term "Young Volcanic" does not indicate "andic" properties such as low bulk densities, exchange complex dominated by amorphous materials, or high content of vitric volcanic ash, cinders or other virtic pyroclastic that pertain to soils in the Andepts Suborder and Andic Subgroups.

SOIL PROFILE CHEMICAL AND PHYSICAL ANALYSIS DATA
AREA: PULANGI 3

SOIL SERIES: Mailag
FINAL MAP SHEET NO.:

LOCATION: Mailag, Valencia Bukidnon
AIRPHOTO OBS/NO.: FL 67-168 / PI

LABORATORY NO.	HORIZON	DEPTH (CM)	LIME TEST	pH H_2O 1:1	pH $CaCl_2$ 1:2	O.C. (%)	O.M. (%)	AVAIABLE P (ppm)	EXTRACTABI K (ppm)
3860	Ap	0-17	0	5.3	4.7	3.2	5.5	4	75
3861	A_{3cn}	17-26	0	5.5	5.4	0.2	0.3	4	57
3862	B1gcn	26-41	0	5.0	4.5	0.7	1.2	2	55
3863	B_{2g}	41-69	0	5.2	5.0	0.6	1.0	10	92
3964	B3g	69-100	0	6.2	5.5	t	t	12	192

HORIZON	DEPTH (CM)	MILLIEQUIVALENTS PER 100 g SOIL: EXCHANGEABLE BASES Ca+Mg	Na	K	SUM	EXCH. ACIDITY	C.E.C. (SUM)	BASE SATURATION	Zn (ppm)	EXCH. Al (ppm)
Ap	0-17	5.0	0.2	0.1	5.3	19.2	24.5	22		
A_{3cn}	17-26	1.6	0.1	0.1	1.8	13.8	15.6	11		
B_{1gcn}	26-41	3.9	0.3	0.1	4.3	12.2	16.5	26		
B_{2g}	41-69	8.5	0.7	0.1	9.3	10.9	20.2	46		
B_{3g}	69-100	10.5	0.8	0.3	11.6	8.0	19.6	59		

HORIZON	DEPTH (CM)	PARTICLE SIZE DISTRIBUTION: TOTAL SAND	SILT (%)	CLAY (%)	TEXTURE CLASS	SETTLING VOLUME (ml)	$CaCO_3$ (%)	ELECTRICAL CONDUCTIVITY (mmho/cm) 1:1	PASTE
Ap	0-17	28	27	45	C	24		0.9	
A_{3cn}	17-26	45	20	35	SCL/CL	21		m	
B_{1gcn}	26-41	38	12	50	C	23		m	
B_{2g}	41-69	38	2	60	C	25		m	
B_{3g}	69-100	45	18	37	SC	24		0.1	

APPENDIX C

List of Soil Series Tentatively Placed in the Order Inceptisols and Major Crops Planted.

C R O P S	S O I L S E R I E S
Rice	Babuyan
	Balongay
	Baluarte
	Bancal
	Barcelona
	Bascaran
	Bay
	Boac
	Buayan
	Butuan
	Cabahuan
	Cahangan
	Calape
	Calumpang
	Candigan
	Catanuan
	Dagani
	Dalacan
	Dawin
	Donsol
	Inton
	Irosin
	Kabacan
	Kapalangan
	Kapatangan
	Kamandag
	Kitcharao
	Lala
	Legaspi
	Malinao
	Mandawe
	Mogpog
	Mambaran
	Palapag
	Palo
	Panganiran
	Pangasinan
	Punupdupan
	Patnongan
	Pawing
	Pilar
	Pili
	Polillo
	Libi
	Libon
	Ligao
	Luisita
	Lutayan
	Mabini
	Makabare
	Makato
	San Miguel
	Sara
	Siaton
	Silay

C R O P S	S O I L S E R I E S
Rice	Sinapangan Sinolan Sorsogon Ramain Tagulod
Corn	Arayat Babuyan Baguio Baliangao Balut Baluarte Baucal Bani Banto Barcelona Bascaran Basco Batuan Bay Bolian Buayan Bulaon Burgos Cadiz Calape Calumpang Candigay Dalican Dagami Dolores Faraon Hernani Ilagan New Iloilo Indan Kabtan Kapatagan Kitcharao Laylay Longa Mambutan Matulas Mayon Medellin Miral Mogpog Panganuran Pangasinan Pasil Patnongan Pilar Salamano San Fabian Libi Libon Ligao Luisita Lutayan Mabini Macalod Magallanes San Manuel

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C R O P	S O I L S E R I E S
Corn	San Pablo
	Sara
	Siaton
	Sobul
	Silay
	Sinapangan
	Sinolan
	Tagaytay
	Tagum
	Tamontaka
	Tarug
	Timaga
	Umingan
	Uyogan
	Villar
	Zaragosa
	Tiptipon
Coconut	Baguio
	Baliangao
	Balongay
	Baluarte
	Bani
	Banto
	Bascaran
	Batuan
	Boac
	Bugko
	Cabahuan
	Cabangan
	Cadiz
	Calape
	Candigay
	Dayami
	Dalican
	Dawin
	Dolores
	Guimaras
	Guinobatan
	Indan
	Kapatagan
	Kaunayan
	Labasan
	La Carlota
	Laylay
	Ligaspi
	Malinao
	Mayon
	Medellin
	Mirall
	Paete
	Palapag
	Palo
	Panganoran
	Paturgan
	Pili
	Polillo
	Palupandan
	Salaman
	Libi
	Libon
	Lutayon
	Maahas
	Mabini

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C R O P S	S O I L S E R I E S
Coconut	Macabari Macalud Sariaya Siaton Sumulong Sorsogon Tagum Tamontaka Tarug Timbo
Sugarcane	Angeles Bago Baluarte Barcelona Basco Batuan Cadiz Calape Calumpang Guimbalaon Indan Kamandag Labasan La Carlota Longa Pasig Patbongan Palupandan Luisita Macolod Magallanes Magcalum San Manuel Sara Silay Sampangan Sorsogon Rugnan Taal
Other Crops	Anao-aon Arayat Babuyan Bad-as Baler Baliangao Balongay Balut Baluarte Bancal Bani Banto Barcelona Bascaran Basco Batuan Bay Boac Bolinao Brookes Buayan Bugko Burgos

C R O P S	S O I L S E R I E S
Other Crops	Busuanga
	Butuan
	Cabangan
	Calapo
	Calatagan
	Calumpang
	Candigay
	Carig
	Matalongon
	Ligao
	Luisita
	Lutayan
	Jamayaon
	Mambutay
	Mabini
	Macabari
	Magallanes
	Magcalon
	Macar
	Novaches
	San Manuel
	San Rafael
	Sariaya
	Silay
	Sinapangan
	Sinolan
	Sorsogon
	Rugnan
	Taal
	Tagum
	Tamontaka
	Tarug
	Tilik
	Timbo
	Titay
	Tugis
	Tupi
	Uiuugaw
	Uyogan
	Villar
	Zaragosa
	Matulas
	Mayong
	Catubig
	New Iloilo
	Tiptipon
Pasture Forest	Libi
	Lunus
	Lutayan
	Maalod
	Magsaysay
	Malalag
	San Rafael
	Santa Fe
	Sta. Maria
	Sariaya
	Serilla
	Sibul
	Sison
	Songsong
	Rizal
	Rugao

C R O P S	S O I L S E R I E S
Pasture Forest	Romblon
	Tagbia
	Tadao
	Atatan
	Abalon
	Anman
	Arayat
	Atok
	Babuyan
	Baguio
	Bakaking
	Banga
	Binangonan
	Bituin
	Bolinao
	Balog
	Brookes
	Bulaon
	Burgos
	Cabangan
	Cervantes
	Coron
	España
	Guimaras
	Guinoang
	Ilagan
	Lamut
	Martalonga
	Mayoyao
	Nangalisan
	Paste
	Palitod
	Paoay
	Pasonanka
	Poguis
	Sabangan
	San Fabian

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ALFISOLS AND ULTISOLS[1/]

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INTRODUCTION

Soils that have significantly more clay in the B horizon than in the A horizon (i.e. soils that have an argillic horizons fall into a number of Orders in Soil Taxonomy. However, the presence of an argillic horizon is a major criteria used to place soils into the Orders of Alfisols and Ultisols. The Ultisols key out after the Histosols, Spodosols, Oxisols, Vertisols and Aridisols while the Alfisols key out only after the Mollisols. Both the Orders of Alfisols and Ultisols must have an argillic horizon but are separated from one another on the basis of their base saturation. Hence clay translocation is the dominant soil forming process for both these Orders. The Ultisols have undergone extensive leaching resulting in low base saturation while the Alfisols only moderate leaching giving rise to moderate to high base status soils.

ALFISOLS

General Concepts

Soils in the order of Alfisols are formed by processes that translocate silicate clays without excessive depletion of bases and without dominance of processes that lead to the formation of a mollic epipedon. The unique properties of Alfisols are a combination of an ochric or umbric epipedon, an argillic horizon, a medium to high supply of bases in the soil and available moisture for plant growth for more than half the year. Because moisture and bases are both not limiting, Alfisols are quite intensively used.

1/ Lecture presented during the XIV International Forum on Soil Taxonomy and Agrotechnology Transfer, March 3-20, 1986, Philippines.

Setting

Due to their high base status, the Alfisols have been called the high base status brown forest soils. From the properties of these soils we can conclude that Alfisols often occur on landscapes which meet the following conditions:

i. allow the existence of moderate amounts of lattice-layer clays.

ii. allow these clays to accumulate in the subsoil by translocation (argillic horizon).

iii. does not favour the formation of a spodic, mollic or other diagnostic horizons.

Alfisols are formed under many climatic zones ranging from a mesic temperature regime to a thermic temperature regime. They often occur on young land surfaces where leaching has not removed the bases. Alfisols are most extensive in humid and subhumid areas. Where the temperature regime is thermic or warmer, Alfisols tend to form a belt between the Inceptisols, and Ultisols and Oxisols. In areas with a mesic or cooler temperature regime, Alfisols form a belt between the Mollisols of the grasslands and the Spodosols and the Inceptisols of the humid climates. The soil moisture regime of these soils is aquic, ustic, xeric or udic.

Under humid temperate climates, Alfisols may occupy most of the landscape, except on very steep slopes, alluvial flood plains and very poorly drained depressions. Under subhumid to arid conditions, Alfisols are commonly confined to borders of depressions where slight concentrations of water have favoured sodium and clay migration to form a natric horizon. High elevations or limited rainfall or concentrations of bases in the parent material favour Alfisols formation in the Tropics (Guerrero, 1963). In general Alfisols are rare in the humid tropics being confine to areas where a recharge of bases from the parent material e.g. limestone or due to addition of bases from volcanic activity occur.

Genesis

A number of processes contribute to the formation of Alfisols. The more important of these are:

i. leaching of carbonates and brownification

ii. elleviation of clay from the A horizon

iii. illuviation of clay into the B horizon

iv. neoformation of clay in the B horizon by weathering

v. moderate to low leaching of bases

In some Alfisols the textural B horizon may be partly destroyed (tonguing of the E) by superficial podzolization. A fragipan or a duripan may also form in the textural B horizon.

Diagnostic Horizons

A variety of diagnostic horizons may occur in Alfisols. Among the epipedons that may be present include the ochric, umbric, anthropic and mollic epipedons. The ochric epipedon is by far the commonest. Subsurface horizons that are common include the argillic, natric and albic horizons. In addition a fragipan, duripan, plinthite or calcic horizon may also be present.

Climatic Regimes

Alfisols are found under a variety of soil moisture and temperature regime. The moisture regimes include the aquic, ustic, xeric and udic. Alfisols occur in areas with a frigid to hyperthermic temperature regimes.

Definition of the Order of Alfisols

The central concept of the Alfisols is that of a soil that has an ochric epipedon, an argillic horizon, moderate to high base status and in which water is held at less than 15 bar tension during at least three months during the months when plants can grow.

Alfisols are mineral soils having:

i. an argillic horizon or natric horizon with a base saturation of greater than 35% at 1.25 m below the top of the Bt horizon or 1.8m below the surface, or at a paralithic contact (whichever is shallower); with or without a fragipan.

ii. no mollic epipedon unless the argillic horizon has in some subhorizon a base saturation of less than 50%.

iii. no spodic horizon overlying the argillic horizon.

iv. no oxic horizon overlying the argillic, no plinthite forming a continuous phase at less than 30 cm.

<u>Key to Suborders</u>

In sub-dividing the Order of Alfisols into Suborders, the main feature used is the soil moisture regime (Fig. 1). The key to the Suborders of Alfisols is as follows:

Alfisols that have an aquic moisture regime or are artificially drained and that have characteristics associated with wetness, namely, mottles, or iron-manganese concretions > 2 mm in diameter, or chroma of 2 or less immediately below any Ap horizon or below any dark A1 horizon in which the moist colour value is less than 3.5 after the material is rubbed, and one of the following:

1. Dominant chroma of 2 or less in coatings on the surface of peds and mottles within peds of the argillic horizon, or a dominant chroma of 2 or less in the matrix of the argillic horizon and mottles of higher chroma;
2. If there are no mottles in the argillic horizon, a dominant chroma of 1 or less.

AQUALFS

Other Alfisols that have:

1. A frigid temperature regime but do not have a xeric moisture regime; or
2. A cryic temperature regime.

BORALFS

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Other Alfisols that have one of the following;

1. An ustic moisture regime;
2. An epipedon that is both massive and hard or very hard when dry and a moisture regime that is aridic but marginal to ustic.
3. Within a depth of 1.5 m of the surface or within a depth of 50 cm below the base of the argillic horizon, a calcic horizon or soft powdery lime in spheroidal forms or as coatings on peds or disseminated in particles of clay size and a moisture regime that is udic but marginal to ustic

USTALFS

Other Alfisols that have one of the following:

1. A xeric moisture regime; or
2. An epipedon that is both massive and hard or very hard when dry and a moisture regime that is aridic but marginal to xeric.

XERALFS

Other Alfisols that have an udic moisture regime.

UDALFS

Great Groups

The five Suborders of the Alfisols are divided into 33 Great Groups. The criteria used at the Great Group level include mean summer soil temperature (at 50 cm) and range of soil temperatures between summer and winter; tonguing of the E horizon into the Bt; abruptness of the E/Bt transition; thickness of Bt; reddish hue of Bt; presence or absence of fragipan, duripan, natric or petrocalcic horizon; presense or absence of plinthite; and percent base saturation in the Bt. The Great Groups are summarized in Table 1.

Subroups

Subgroups in the Alfisols reflect the relationship of these soils with several other Orders that border the modal Alfisol ecological situation e.g. Mollic Ochraqualf.

Drainage differences commonly noted in a drainage catena of Alfisols are reflected in the Suborder and Subgroup classification. For example, a well-drained soil would be the Typic Hapludalf; the moderately well to imperfectly drained soil and an Aquic Hapludalf; the somewhat poorly drained Aeric Ochraqualf and the very poorly drained soil is a Typic Ochraqualf or Typic Umbraqualf.

ULTISOLS

General Concepts

Soils in the Order of Ultisols are formed by processes that translocate silicate clays coupled with excessive leaching of bases. Thus the unique properties common to Ultisols are an argillic horizon, a low supply of bases, particularly in the lower horizons, and a mean annual soil temperature higher than $8^{o}C$ ($47^{o}F$). The horizon of clay accumulation may be thin or thick. The cation exchange capacity in Ultisols is mostly moderate to low. The decrease in base saturation with depth reflects cycling of bases by plants or addition in fertilizers. Like Alfisols, the Ultisols have enough moisture, but have few bases. Without fertilizers, they can be used for shifting cultivation, but can be made highly productive if fertilizers are used as Ultisols are warm and moist.

Setting

The intensive leaching which Ultisols have undergone is often a result of leaching by intensive precipitation on a stable or geomorphologically old landscape. This intensive weathering and leaching results in deep low base status soils. As such Ultisols are more common in the intertropical regions where warm humid conditions and old landscapes occur. However, Ultisols are by no

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means confined to tropical latitudes. In the tropics the Ultisols occupy the relatively younger geomorphic positions compared to Oxisols with which they are often associated. However, when Ultisols are associated with Alfisols, the Ultisols are on the more stable landscapes and Alfisols on the younger sideslopes. Thus Ultisols often occur on landscapes which meet the following conditions:

i. allow the existence of moderate amounts of lattice-layer clays.

ii. allows these clays to be translocated and accumulated in the subsoil (argillic horizon).

iii. does not favour the formation of a spodic, mollic or other diagnostic horizons.

Ultisols are formed under a variety of climatic zones. They are common soils of the mid to low latitudes. The soil moisture regime is not perudic, but at some season there is an excess of precipitation over evapotranspiration and water moves through the soil and into a warm moist substratum. The release of bases by weathering is usually equal to or less than the removal by leaching, and mormally most of the bases are held in the vegetation and upper few centimeters of the soils.

Ultisols are most extensive in warm humid climates that have a seasonal deficit of precipitation. They occur over a variety of parent materials but very few have primary minerals. The Ultisols may have any soil temperature regime warmer than frigid or isofrigid. They may have an aquic, udic, xeric or ustic soil moisture regimes.

Genesis

A number of processes contribute to the formation of Ultisols. The more important of these are:

i. excessive leaching

ii. eluviation of clay from the A horizon

iii. illuviation of clay in the Bt horizon

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iv. neoformation of clay in the B horizon by weathering

v. small amount of podzolization

In some Ultisols the textural B horizon is often overlain by a thick E horizon. This E horizon may be sandy textured while the Bt horizon clayey. A fragipan or plinthite may also occur in these soils.

Diagnostic Horizons

A number of diagnostic horizons and features may occur in Ultisols. The epipedons that commonly occur are ochric, umbric, anthropic and mollic. The subsurface horizons and features common in Ultisols include argillic, albic, fragipan and plinthite. Ultisols occur in soils having as isomesic or warmer soil temperature regime. The moisture regimes common to Ultisols are aquic, ustic, xeric and udic.

Definition of the Order of Ultisols

The central concept of the Ultisols is that of a soil that has an ochric epipedon, an argillic horizon, low base status and in which there is sufficient moisture for at least three months for plants to grow.

Ultisols are mineral soils that:

1. Do not have tongues of albic materials in the argillic horizon that have vertical dimensions of as much as 50 cm if there is 10% weatherable minerals in the silt fraction, but have one of the following combination of characteristics:

   a. Have an argillic horizon but not a fragipan and have base saturation (sum of cations) of $<35\%$ within the following depths:

      i. If the argillic horizon has in some part a hue of 5YR or yellower, or a colour moist of 4 or more, or a colour value dry that is more than

1 unit higher than the value, moist, the shallowest of the following:

a. 1.25 m below the upper boundary of the argillic horizon.

b. 1.8 m below the surface of the soil or

c. Immediately above a lithic or paralithic contact.

i. If the argillic horizon has some other colour or if the epipedon has a sandy or sandy - skeletal particle - size class throughout, the deeper of 1.25 m below the upper boundary of the argillic horizon or 1.8 m below the surface of the soil, or immediately above a litchic or paralithic contact if it is shallower.

b. Or have a fragipan that

i. Meets all the requirements of an argillic horizon, or has clayskin > 1 mm thick in some part, or underlies an argillic horizon and

ii. Has base saturation (by sum of cations) of < 35% at a depth of 75 cm below the upper boundary of the fragipan or immediately above a lithic or paralithic contact, whichever is shallower.

2. Have a mesic, isomesic or warmer temperature regime

3. Do not have a spodic horizon, and do not have an oxic horizon unless it underlies an argillic horizon; and

4. Do not have plinthite that forms a continuous phase within 30 cm of the soil surface.

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Key to Suborders

In separating the Ultisols into Suborders two criteria have been used. The soil moisture regime and the amount of organic carbon in the upper part of the argillic horizon have been used to subdivide the Order of Ultisols (Fig. 2) into five Suborders as follows:

Ultisols, either saturated with water at some time of the year or artificially drained, that have characteristics associated with wetness, namely mottles, iron-manganese concretions > 2 mm in diameter, or chroma, moist of 2 or less immediately below any Ap or A1 horizon that has a value, moist, of less than 3.5 when rubbed; and also one or more of the following:

1. Dominant chroma moist of 2 or less in coatings on the surface of peds and mottles within the peds, or dominant chroma of 2 or less in the matrix of the argillic horizon and mottles of higher chroma (if the hue is redder than 10YR because of parent materials that remain red after citrate-dithionite extraction, the requirement for low chroma is waived);
2. Chroma, moist, of 1 or less on surface of peds or in the matrix of the argillic horizon; or
3. Dominant hue of 2.5Y or 5Y in the matrix of the argillic horizon and distinctt or prominent mottles and also a thermic or isothermic or warmer soil temperature regime.

AQUULTS

Other Ultisols that have either or both of the following characteristics:

1. Have 0.9 percent or more organic carbon in the upper 15 cm of the argillic horizon; or
2. Have 12 kg or more organic carbon in the soil per square meter to a depth of 1 m below the base of the mineral soil surface, exclusive of any 0 horizon that may be present.

HUMULTS

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Other Ultisols that have a udic moisture regime.

UDULTS

Other Ultisols that have an ustic moisture regime.

USTULTS

Other Ultisols that have a xeric moisture regime.

XERULTS

Great Groups

The five Suborders of the Ultisols are further subdivided into 22 Great Groups. The criteria used in this subdivision are the presence or absence of various soil features such as plinthite, fragipan, iso-temperatures, clay distribution with depth, ochric epipedon and colour value of less than 4 in the argillic horizon. The Great Groups are summarized in Table 2.

Subgroups

Subgroups in the Ultisols as is the case of Alfisols reflect the relationship of these soils with several other Orders that border the modal Ultisols e.g. Spodic Paleudults.

Drainage differences commonly noted in a drainage catena of Ultisols are reflected in the Suborder and Subgroup classification. For example, a well drained soil would be the Typic Tropudult; the moderately to imperfectly drained soil would be Aquic Tropudult; the somewhat poorly drained an Aeric Tropaquult and the poorly drained member a Typic Tropaquult.

Table 1. Suborders and Great Groups in the Alfisols Order

SUBORDER	GREAT GROUPS	
Aqualfs	Natraqualfs	- presence of a natric horizon
	Tropaqualfs	- MAT* $>$ 8°C (47°F) and summer and winter temperature differ less than 5°C (9°F) at 50 cm
	Fragiaqualfs	- presence of a fragipan
	Glossaqualfs	- albic horizon tonguing into the argillic horizon and no duripan present
	Albaqualfs	- abrupt textural change from albic to argillic horizon
	Ochraqualfs	- presence of an ochric epipedon
	Umbraqualf	- presence of an umbric epipedon
Boralfs	Paleboralfs	- upper boundary of argillic horizon deeper than 60 cm (24 in) and textures finer than loamy fine sand in some layer above the argillic horizon
	Fragiboralfs	- presence of a fragipan
	Natriboralfs	- presence of a natric horizon
	Cryoboralfs	- mean summer temperature at 50 cm (20 in) or shallower lithic or paralithic contact of less than 15°C (59°F) without an 0 horizon { $<$ 8°C (47°F) MST + with an 0 horizon }
	Eutroboralfs	- base saturation $\geq$ 60% in all parts of argillic horizon and dry in some horizon part of each year
	Glossoboralfs	- either never dry or have a base saturation $<$ 60% in some part of the argillic horizon
Ustalfs	Plinthustalfs	- plinthite present within 1.25 m (50 in) of the surface
	Durustalfs	- duripan present below argillic or natric horizon but within 1 m (40 in) of the surface
	Natrustalfs	- presence of a natric horizon
	Paleustalfs	- presence of a petrocalcic horizon within 1.5 m (60 in) of the surface or a thick dense argillic horizon
	Rhodustalfs	- argillic horizon colour redder than 5YR
	Haplustalfs	- other Ustalfs
Xeralfs	Plinthoxeralfs	- presence of plinthite within 1.25 m (50 in) of the surface
	Durixeralfs	- presence of a duripan within 1 m (40 in) of the surface
	Natrixeralfs	- presence of a natric horizon
	Rhodoxeralfs	- argillic horizons redder than 5YR
	Palexeralfs	- solum thicker than 1.5 m (60 in) of the surface
	Haploxeralfs	- other Xeralfs
Udalfs	Agrudalfs	- presence of an agric horizon
	Fragiudalfs	- presence of a fragipan
	Natrudalfs	- presence of a natric horizon
	Tropudalfs	- mean summer and mean winter temperatures at 50 cm (20 in) or lithic or paralithic contact, if shallower, differ by less than 5°C (11°F)
	Ferrudalfs	- presence of a discontinuous albic horizon and discrete iron nodules 2.5 to 5 mm in diameter in the argillic horizon

Table 1 (continuation)

SUBORDER	GREAT GROUPS	
	Glossudalfs	- presence of an albic horizon which tongues into the argillic horizon
	Paleudalfs	- sola deeper than 1.5 m (60 in) have a clay distribution that decreases less than 20% of its maximum within the 1.5 m (60 in) depth
	Hapludalfs	- other Udalfs

*MAT = mean annual temperature

+MST = mean summer temperature

Table 2. Suborders and Great Groups in the Ultisols Order

SUBORDER	GREAT GROUPS	
Aquults	Plinthaquults	- plinthite forms over one-half of a horizon within 1.25 m (50 in) of the surface
	Fragiaquults	- presence of a fragipan
	Tropaquults	- mean summer and mean winter temperatures differ less than 5°C (9°F)
	Paleaquults	- less than 10% weatherable minerals in the upper 1 m (40 in) and a clay distribution such that the clay content does not decrease more than 20% within 1.5 m (60 in) of the surface
	Ochraquults	- presence of an ochric epipedon
	Umbraquults	- presence of an umbric or mollic epipedon
Ustults	Plinthustults	- plinthite layer within 1.25 m (50 in) of the surface
	Paleustults	- less than 10% weatherable minerals in the 20-200 μ separate within 1 m (40 in) and a clay distribution with less than 20% decrease within 1.5 m (60 in) of the surface
	Rhodustults	- moist colour value less than 4 in all parts and argillic horizon colour values less than 5
	Tropustults	- mean summer and mean winter temperatures differ less than 5°C (9°F)
	Haplustults	- all other Ustults
Xerults	Paleudults	- less than 10% weatherable minerals in the 20-200 μ separate of the upper 1 m (40 in) and less than 20% clay content decrease within 1.5 m (40 in) of the surface
	Haploxerults	- other Xerults
Humults	Palehumults	- less than 10% weatherable minerals in the 20-200 μ separate of the upper 1 m (40 in) and less than 20% decrease in clay content to a depth of 1.5 m (60 in)
	Tropohumults	- mean summer and mean winter temperatures differ by less than 5°C (9°F)
	Haplohumults	- other Humults
Udults	Fragiudults	- presence of a fragipan
	Plinthudults	- plinthite layer within 1.25 m (50 in) of the surface
	Paleudults	- less than 10% weatherable minerals in the 20-200 μ separate of the upper 1 m (40 in) and less than 20% decrease in clay content to a depth of 1.5 m (60 in)
	Rhodudults	- moist colour value of epipedon less than 4 and dry argillic horizon colour values less than 5
	Tropudults	- mean summer and winter temperatures differ by less than 5°C (9°F)
	Hapludults	- all other Udults

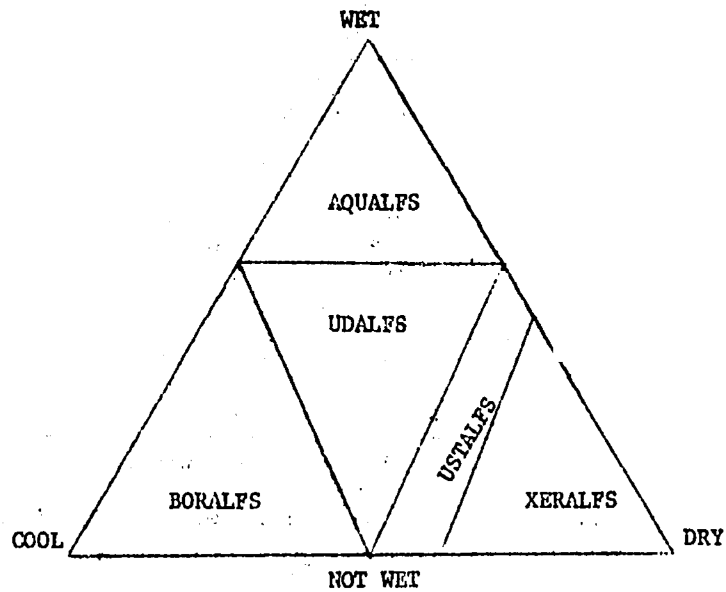

Fig. 1. Key to Suborders of Alfisols

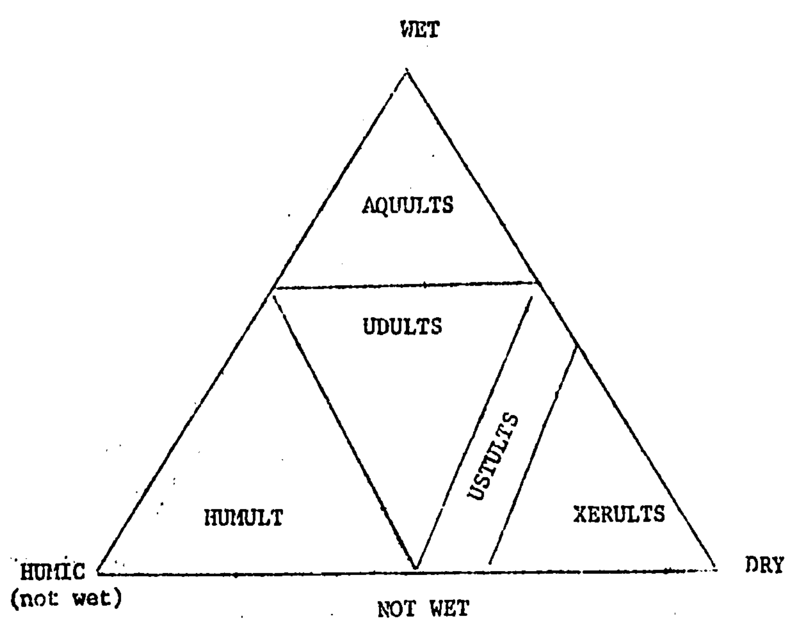

Fig. 2. Key to Suborders of Ultisols

MOLLISOLS[1/]

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INTRODUCTION

The Mollisols include most soils that have been called Chernozem, Brunizem (Prairie), Chestnut, and Reddish Prairie, and the associated Humic Gley soils and Planosols. They also include those Renzinas, Brown soils, Reddish Chestnut soils, and Brown Forest soils that have a mollic epipedon.

The vast majority of the Mollisols have developed under a grass vegetation, although many apparently have been forested at an early time. A few that formed from chalk or marl have apparently formed under forest. Most of these soils in high latitudes have formed in late - Pleistocene or Holocene deposits. Beyond the limits of glaciation, Mollisols may be in older deposits of on older surfaces dating back perhaps to mid - Pleistocene or earlier, and these normally have an argillic horizon that has a reddish hue.

The climatic range of Mollisols is from boreal or alpine to tropical. Rainfall may be sufficient to provide some annual leaching through the soil in most year, or it may only be moisture in the solum. Dry season are normal.

GENESIS

The relative thick, dark - colored, humus - rich, and dominant bivalents of Mollisols, from a genetic point of view is thought to be formed as the process called "Malanization". The process consists of the underground decomposition of organic residues under the presence of bivalent cations environment. The residues are decomposed partly from roots and partly from the surface that have been taken underground by animals.

1/ Lecture presented during the XIV International Forum on Soil Taxonomy and Agrotechnology Transfer, March 3-20, 1986, Philippines.

DIAGNOSTIC HORIZONS

The following horizons may occur in the Mollisols

Epipedon	:	mollic
Subsurface	:	cambic, argillic, albic, natric, calcic, petrocalcic horizon, and duripan
Soil moisture regime	:	aquic, ustic, udic, xeric, aridic
Soil temperature regime	:	frigid to hyperthermic

DEFINITION

Mollisols are mineral soils that

1. Meet one of these two requirements
   a. Have a mollic epipedon or
   b. have a surface horizon after mixed to a depth of 18 cm. meet all requirements of a mollic epipedon and
2. have base saturation (NH_4OAc) of 50% or more as follows:
   a. presence of argillic or natric horizon
      - to a depth 1.25 m. below the upper boundary of argillic or natric horizon, or
      - to a depth 1.8 m. below the soil surface or to a lithic or paralithic contact, whichever is least.
   b. absence of argillic or natric horizon
      - to a depth 1.8 m. below the soil surface or to a lithic or paralithic contact, whichever is least: and
3. have bulk density (1/3 bar water tension) 0.85 or more if exchange complex is dominated by amorphous material and have less than 60% vitric volcanic ash, cinders or other pyroclastic material in the silt, sand and gravel fractions.

KEY TO SUB - ORDERS OF MOLLISOLS

At the Sub - Orders level Mollisols are separated using the soil moisture regimes, presence of albic horizon and other soil properties.

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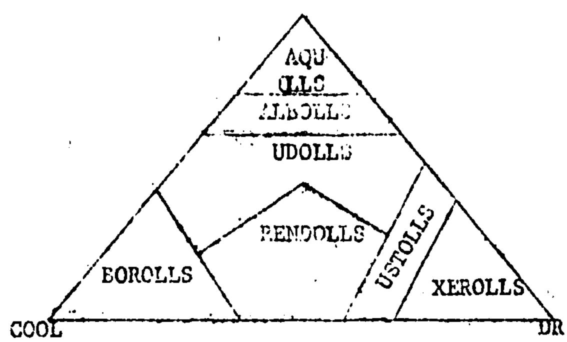
The Sub - Orders are summarized in the diagram below:



KEY TO GREAT GROUPS OF MOLLISOLS

The Sub - Orders of the Mollisols are separated into Great Groups using the presence of specific diagnostic horizons, properties or soil temperature regime. The criteria used include the following:

natric horizon

argillic horizon

cambic horizon

calcic horizon

cryic or pergelic temperature regime

distribution of clay content in the profile

presence of krotavinas

The Sub - Orders and Great Groups are given in the table below:

Suborder and great groups of the Mollisol order

SUBORDER	GREAT GROUP	
Albolls	Natralbolls	- presence of natric horizon
	Argialbolls	- presence of argillic horizon

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SUBORDER	GREAT GROUP	
Aquolls	Cryaquolls	- have a cryic or pergelic temperature regime
	Duraquolls	- presence of a duripan
	Natraquolls	- presence of natric horizon
	Calciaquolls	- presence of calcic horizon
	Argiaquolls	- presence of argillic horizon
	Haplaquolls	- presence of cambic horizon
Borolls	Paleborolls	- presence of argillic horizon at greater than normal depth
	Cryoborolls	- have a cryic or pergelic temperature regime
	Natriborolls	- presence of natric horizon
	Argiborolls	- presence of an argillic horizon close to the surface
	Vermiborolls	- presence of warmholes, warmcasts or filled animal borrows
	Calciborolls	- presence of calcic or petrocalcic horizon
	Haploborolls	- presence of cambic horizon
Rendolls	No great group developed	
Udolls	Paleudolls	- presence of argillic horizon, clay content does not decrease by 20% from the maximum
	Argiudolls	- presence of argillic horizon
	Vermiudolls	- presence of wormholes, wormcasts of filled animal burrows
	Hapudolls	- presence of cambic horizon
	Duriustolls	- presence of a duripan
	Natrustolls	- presence of a natric horizon

SUBORDER	GREAT GROUP	
Ustolls	Paleustolls	- presence of petrocalcic and argillic horizon within 1.5 m/clay does not decrease by 20% from the maximum
	Calciustolls	- presence of calcic horizon
	Argiustolls	- presence of argillic horizon
	Vermustolls	- presence of wormcasts, wormholes or filled animal burrows
	Haplustolls	- presence of cambic horizon
	Durixerolls	- presence of duripan
	Natrixerolls	- presence of natric horizon
Xerolls	Palexerolls	- presence of petrocalcic horizon or argillic horizon
	Calcixerolls	- presence of argillic horizon
	Argixerolls	- presence of argillic horizon
	Haploxerolls	- presence of cambic horizon

HISTOSOLS[1]

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INTRODUCTION.

The physical and chemical properties of organic soils are vastly different those of mineral soils. Because of the unique properties of organic soils, pedologists have grouped them seperately in the past and the authors of <u>Soil Taxonomy</u> identified them at the highest categorical level by creating the Histosol order. Histosol is from the Greek word Histos, meaning a web, and now used as a combining form meaning tissue.

Figures 1 and 2 show the distribution of organic soils (peat) in the world and in the United States, respectively. Peat areas occur in all climatic zones on all continents but are most common and extensive between latitudes 50 and 70 because of past glaciation and temperature-moisture interrelationships that favor organic matter accumulation at those latitudes. Finland has almost a third of its land area covered by peat while Sweden, Ireland, Canada, Hungary, Scotland, and Norway all have more than 10 percent of their areas covered by peat. Not all of these areas would qualify as Histosols, however. Maritime climates also favor the formation of Histosols in low lying coastal areas. They occur along the east coasts of North America and Asia.

Everett (1983) points out that organic matter accumulates under reducing or anaerobic conditions that are decidedly unfavorable for the biodegradation of organic matter. This implies adequate to excessive moisture, frequently combined with low temperatures. Precipitation usually exceeds evapotranspiration.

In addition to the organic soils formed under saturated conditions, freely drained Histosols occur as relatively thin accumulations of organic plant litter on rocks (blanket bogs). The order Histosols accommodates both types, but the saturated ones are much more extensive and economically important. For the freely drained organic soils (Folists) to qualify as Histosols, they must contain 20 percent organic carbon compared to a minimum organic carbon requirement of 12 percent for the saturated Histosols.

1/ Lecture presented during the XIV International Forum on Soil Taxonomy and Agrotechnology Transfer, Philippines.

For the saturated Histosol suborders, the minimum organic carbon requirement varies with the clay content. Because clay and organic carbon are commonly the main chemically active soil components, the requirements for Histosols are intended to insure that organic matter is chemically dominant. As clay content increases from 0 to 60 percent, organic carbon content must increase from 12 to 18 percent. With no clay, organic carbon must be at least 12 percent and, if clay is 60 percent or more, organic carbon must exceed 18 percent. The proportinal requirements are shown graphically on figure 3. There is a lower organic carbon requirement (8-12 percent) for plowed histic epipedons. Normally, data sheets express mineral content (determined by dry combustion at 400°C) and organic carbon content (determined by wet combustion). The wet combustion method (Walkley-Black) is reliable up to about 10 percent organic carbon. The mineral content values are, therefore, preferred. The dry combustion method may not be reliable when samples contain amorphous material or gypsum.

Among the Histosols that are usually saturated, the degree of decomposition, because of its impact on the soil's physical conditions, is used as suborder criteria. The degree of decomposition relates somewhat to the type of vegetation undergoing decomposition, but perhaps more to water table fluctuation. The more highly decomposed Histosols are normally ones with a fluctuating water table that allows for more oxidation within the soil than in the less decomposed soils wheere water tables are shallow and static. In the field, we are able to identify degree of decomposition based on the presents or absence of identifiable plant tissue fibers. They are easily identifiable and dominant in fibric horizons and are absent in sapric horizons. Hemic horizons are intermediate. These properties are also observable in thin sections. With increasing decomposition, Histosols become more dense and lose the sponge-like properties. As noted in <u>Soil Taxonomy</u> (Soil Survey Staff, 1975) bulk densities common in fibric horizons are ≤0.1 g/cc, between .07 and .18 in hemic materials, and 0.2 or more in sapric materials. As the bulk densities vary, the potential water holding capacity also varies. Saturated moisture contents, as a volume percent, might be just less than 100 in fibric materials, 85-90 percent in hemic materials, and greater than about [illegible]-85 percent in sapric materials. Although saturated moisture percentages are not strikingly different, moisture retained against 0.1 bar suction is more varied and more important to crop production. They would typically be near 75 percent for sapric, near 60 percent for hemic, but near 30 percent for fibric materials (Boelter, 1969).

The degree of decomposition is operationally defined by both physical and chemical criteria. The suborder criteria are shown graphically on figure 4. The definitions are as follows:

<u>Fibric</u>: >75 percent rubbed fiber, or ≥ 40 percent rubbed fiber and light pyrophosphate color. Most fibric materials are formed from sphagnum mosses.

<u>Sapric</u>: <17 percent rubbed fiber and dark pyrophosphate colors and are the most decomposed organic soils. Nearly all cultivated organic soils have sapric surfaces. Shallow (terric) organics are usually sapric.

<u>Hemic</u>: Fail to meet the requirements for sapric or fibric. Hemic soils are commonly straw yellow. Some appear highly fibrous, but fibers disintegrate when rubbed.

The fiber content criterion directly measures the degree of decomposition. The color criterion is an application of our knowledge that as organic materials decompose, more humic are formed. The darker colored humic acid in the pyrophosphate extract relates to the degree of decomposition.

Great group criteria of Histosols are primarily based on temperature regimes (Cry, Boro, Tropo). One exception is that of Sulfahemists. All Histosols containing sulfidic materials are classified as hemists regardless of the degree of decomposition. It was felt that these soils should be grouped together because of the large impact of the sulfur.

Thicker organic layers are required for fibric materials than for sapric or hemic materials. These criteria relative to the potential subsidence that occurs when the soils are drained. Fibric material is less dense and would subside more than sapric material if it were drained for farming.

Histosols are important timber and vegetable crop production soils so a few points about their exchange capacity compared to mineral soils is useful. The following is a comparison of the surface horizon exchangeable calcium of two Minnesota soils from the northern United States.

PROPERTY	TYPIC BOROHEMIST (Oa)	AQUIC HAPLOBOROLL (Ap)
Ca (meq/100 g)	145	5.4
Bulk Density (g/cc)	0.04	1.48
Ca (meq/cm^3)	5.80	8.0

These data emphasize that, although a nutrient expressed as a weight percentage in organic soils are comparatively large values, they are sharply decreased if expressed as a volume percent. Since plant roots ramify a soil volume rather than a soil weight, a volume expression provides a more meaningful method of comparing nutrient content between organic and mineral soils. Other nutrient expressions and the cation exchange capacity are also high when expressed as weight percentages in Histosols, but more nearly like mineral soils when expressed as a volume percent. These soils have a large pH-dependent charge, so the effective CEC (sum of cations plus KCl aluminum) is the most useful CEC expression for agronomic uses. Fairly typical Histosol data are shown in table 1, data from a Minnesota Borosaprist.

Nutrient status of Histosols is quite variable and depends, to a large extent, on the dissolved nutrients in the water feeding the organic soils. This, in turn, affects the type of plants that grow on a given Histosols. Frequently Histosols require liming for production of cultivated crops. Requirements for additional plant nutrients as fertilizer are variable, but commonly potassium and micronutrients are deficient in Histosols.

Histosols require careful management when drained and cultivated to control the loss of soil material by oxidation and wind erosion. Water tables are usually carefully controlled to optimize crop production and minimize soil loss.

We have discussed the properties of Histosols and their placement in Soil Taxonomy as well as some of the criteria for placement. Additional discussion and more specific criteria are discussed in Chapter 1, of "Pedogenesis and Soil Taxonomy, II. The Soil Orders" (Everett, 1983).

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MINERALOGY OF SOILS[1/]

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Soil mineralogy is considered one of the most important determinants of the soil capability. In rice production for example, strongly weathered soils in which the clay fraction is dominated iron oxide and kaolinite are considered poor soils for rice. Soils acquire most of their properties from the minerals they contain although some of the manifestations are hardly differentiable from the influence of soil texture. These properties include water retention capacity, permeability, plasticity, shrinkage swelling, and cation-exchange capacity. The importance that soil mineralogy plays in soil classification is recognizable even in the old system where certain soil groupings embody certain properties unique to certain mineralogical component. In Soil Taxonomy (1975), mineralogical composition appears at the family level of the classification scheme.

The objective of this paper is to discuss the common soil minerals, their properties, and their implications to soil management. Emphasis will be given to tropical soils with regards to the influence of soil minerals on their characteristics.

The minerals commonly found in soils are given in Figure 1. These include the crystalline and non-crystalline fractions of soil inorganic material.

Soil Taxonomy (1975) recognizes 15 mineralogical classes not including mixed mineralogies as follows:

<u>OXIDES AND HYDROUS OXIDES</u>

Ferritic	Oxidic
Gibbsitic	Siliceous

1/ Paper presented at the XIV International Forum on Soil Taxonomy and Agrotechnology Transfer for the ASEAN region, held in the Philippines.

- SOIL CONSTITUENTS
  - WATER
  - SOLID
    - INORGANIC
      - CRYSTALLINE
        - Oxides and hydrous oxides of Fe, Al, Mn, Si, and Ti
        - Silicates
        - Slightly soluble salts
        - Soluble salts
      - NON-CRYSTALLINE
        - Hydrous oxides of iron, aluminum and silicon
          1) plant opal
          2) hydrated gels
        - Alumino-silicates
          1) allophane
          2) imogolite
          3) glass
    - ORGANIC
  - AIR

Figure 1. Minerals commonly found in soils.
(After Uehara, 19).

SILICATES

Chloritic	Kaolinitic
Glauconitic	Micaceous
Halloysitic	Montmorillonitic
Illitic	Serpentinic

SOLUBLE SALTS

Carbonitic	Gypsic

MINERALOGICAL COMPOSITION OF SOILS

The same factors of soil formation determines the occurrence of clay minerals in soils. Those factors are: parent material, relief, time, biotic factors, and climate. Largely because of climate, a significant proportion of soils in the temperate region differs from those of the tropical region. Soil temperature and moisture are two climatic factors that determine much of the differences between soils developed in the humid tropical zone and those in the temperate zone. A soil developed in the humid tropical zone, is usually more weathered than one developed in the temperate zone. Consequently, minerals frequently found in tropical soils belong to the more weathered members of the series such as kaolinite and gibbsite. This can be easily understood if one follows the weathering of feldspar to mica or montmorillonite to kaolinite and then to gibbsite. The rapid loss of potassium from feldspar under high temperature and high leaching environment facilitates the weathering of this mineral to kaolinite or gibbsite.

A. Primary minerals in soils

The primary minerals in the soil make up bulk of the sand and silt fractions of most soils. The most abundant primary soil minerals are quartz and feldspars (Jackson, 1964). Potassium feldspars occur commonly in the course fractions but may also be abundant in the clay-size fraction of very young soils. Pyroxenes, amphiboles, olivine and other accessory minerals may be present in smaller percentages.

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B. <u>Carbonate minerals in soils</u>

Calcite is the most abundant carbonate mineral in soils. Calcite could be inherited from limestone, marl, chalk and marble parent materials or formed in the soil as it accumulates in the C horizon of some soils in sub-humid and arid regions.

C. <u>Layer silicate or phyllosilicate minerals</u>

The layer silicate or phyllosilicate soil minerals are classified under three types, namely 1:1, 2:1, and 2:1:1. These numbers refer to the layer silicate structures which are formed by the tetrahedral silica sheets attached to octahedral hydroxyl sheets.

The 1:1 type layer silicates common in soils are kaolinite and halloysite. The layers are composed of a tetrahedral sheet and an octahedral sheet in which the valency of Si and Al are satisfied by four oxygen atoms for Si and six for Al but one of the oxygen for Al is shared with a Si through which the silica sheet and the octahedral sheet are combined. Successive layers are joined together by H bonds giving 7.2 A X-ray interval. Isomorphic substitution in the crystal structure is very little compared to other layer silicates. The almost fixed layers and limited substitution in the lattice accounts for the low CEC, limited surface area, very low plasticity, and non-expandability of the layers.

Halloysite resembles kaolinite except that a layer of water is hydrogen-bonded in the interlayer position. The unequal distribution of forces in the lattice causes the expansion of the tetrahedral sheet, hence the curling or tubular structure of the mineral. The structure in which the interlayer position is fully hydrated contains a maximum of four water molecules per formula weight and is known as endellite or hydrated halloysite. The structure from which the water in the interlayer has been removed is called halloysite or metahalloysite.

The 2:1 type layer silicates occuring extensively in soils are montmorillonites, vermiculites, and micas. These layer silicate minerals are composed of two silica tetrahedral sheet per octahedral sheet. The montmorillonites have some isomorphic substitution in the crystal lattice but largely in the tetrahedral sheet where Al substitute for Si. This substitution creates a net charge for the crystal structure. Substitution in montmorillonite may also occur in the tetrahedral sheet by P for Si and/or Mg, Fe, Zn, Ni, and Li for Al in octahedral coordination. These substitution creates a permanent negative charge within the lattice which may be neutralized by cations in the interlayer positions.

The montmorillonites or smectites have freely expansible layers due to the weak bonds between layers. The spacing ranges from 12 to 18 A and varies with the cation species and degree of solvation of the cations in the interlayer. Complete dehydration gives a spacing of less than 10 A while full hydration expands the layers completely apart. This accounts for the large surface area, shrink-swell characteristi and high plasticity and cohesion in montmorillonite.

Vermiculite has a structure similar to montmorillonite except it has more substitution in the lattice resulting in greater charge density. Substitution in vermiculite is predominantly in the tetrahedral sheet which results in closer bond of the exchangeable cations in the interlayer position with the negatively charged layers and limiting expansion to about 4.98 A only.

Mica has same basic structure as montmorillonite and vermiculite except that in mica some Si in the tetrahedral sheet are substituted by Al which is the reason for its greater charge density than vermiculite. The layers in mica, however, are held strongly together by K in the hexagonal positions in the interlayer space. Consequently, the layers are fixed and interlayer space does not contribute to cation exchange.

The 2:1:1 type is like the 2:1 type with an additional octahedral sheet in the layer. This additional sheet has Mg or Al in octahedral coordination. The substitution of Al for Mg create positive charge in this additional sheet. Minerals under this type are known as chlorites which have low surface area and cation exchange capacity.

D. Oxide and hydrous oxide minerals

The oxide and hydrous oxide minerals occur extensively in soils. As soils become intensively leached, the removal of Si results in the accumulation of Fe, Al, and Ti in the form of hydrous oxides. These minerals range from highly crystalline to non-crystalline and posses variable and pH-dependent charges.

Gibbsite is the most abundant free hydrous oxide of alumina in highly weathered soils of the tropical and subtropical regions. Gibbsite is crystalline but amorphous hydrous oxides of aluminum also occur. Boehmite occurs in intensively leached and highly weathered soils usually together with gibbsite.

The most common iron oxides in soils are hematite and and goethite. Hematite may occur in silt and sand fractions of Oxisols. Iron oxides of soils are usually derived from weathering of iron-bearing minerals. Under poorly drained soil conditions lepidocrocite, an isomer of goethite, may occur as reported in some rice soils in Japan (Kojima and Kawaguchi, 1968a, b). Magnetic iron oxides, magnetite and maghemite, occur in the sand and silt fractions of certain highly weathered soils.

Titanium oxide minerals common in soils are rutile and anatase. Rutile may be derived from parent rocks while anatase may be formed during soil weathering. Another titanium oxide is iliminite (together with iron oxide) is common in Hawaiian soils. It is believed to be derived from mafic rocks.

E. Allophane

Allophanes are "members of a series of naturally occurring minerals which are hydrous aluminum silicates of widely varying chemical composition, characterized by short range order, by the presence Si-O-Al bonds, and by a differential thermal analysis curve displaying a low temperature endotherm and a high temperature exotherm with no intermediate endotherm" (van Olphen, 1971). Allophanes are generally amorphous to X-ray, soluble in excess strong alkali, release OH on addition of F, exibits a high pH-dependent CEC, and strongly associated with organic matter in Andisols.

MINERALOGY OF RICE SOILS

Studies of rice soils in the Asian region showed many kinds of minerals besides the major primary and secondary minerals (Kyuma, 1978) These minerals include lepidocrocite, siderite, jarosite, and vivianite (Kyuma, 1978). Lepidocrocite (γ- FeOOH) was found dominant in most Japanese rice soil samples but was not found in samples from tropical Asia. Siderite is a ferrows carbonate, found in permanently wet rice soils. Its nodules or concretions turn from white to brown when exposed to air. Jarosite $[KFe_3(SO_4)_2(OH)_6]$ is straw-yellow colored mottles found in soils of brackish sediment origin and usually associated with acid-sulfate soils. Vivianite $[Fe_3(PO_4)_2 \cdot 8H_2O]$ may be formed in highly reducing high phosphorus conditions. It could be seen as whitish mottles which becomes purple when exposed to the air.

MINERALOGY AND SOIL ORDERS

The dominant clay minerals of the various soils orders for mineral soils are listed Table 1. The differences among the soil orders will not be tackled in this paper since it is assumed that a lengthy discussion has been provided earlier.

Table 1. Dominant clay mineral types in various soil orders. (Fom M.L. Jackson, 1964 with slight modification)

ORDER	DOMINATN CLAY MINERALS
Inceptisol	Allophane, mica, interstratified layer silicates
Mollisol	Smectites, mica, vermiculite, chlorite
Alfisol	Illite, smectites, 2:1 to 2:1:1 intergrades, chlorite, kaolinite
Ultisol	Kaolinite, halloysite, vermiculite, 2:1 to 2:1:1 intergrades, sesquioxides, gibbsite
Oxisol	Sesquioxides, gibbsite, kaolinite, 2:1 to 2:1:1 intergrades
Aridisol	Illite, vermiculite, chlorite, interstratified layer silicates, chlorite
Entisol	Highly variable
Vertisol	Smectites
Spodosol	Sesquioxides, interstratified layer silicates, 2:1 to 2:1:1 intergrades, illite

Table 2. Cation exchange capacities and surface area of soil minerals (Adopted from Zelazny and Calhoun, 1971)

SOIL MINERALS	C. E. C. M'EQ/100g	SURFACE AREA m^2/g
Kaolinite	3-15	7-30
Metahalloysite	5-10	10-45
Halloysite	10-40	10-45
Montmorillonite	80-150	600-800
Dioctahedral vermiculite	10-150	50-800
Trioctahedral vermiculite	100-200	600-800
Muscovite	10-40	60-100
Illite	10-40	65-100
Allophane	5-350	10-800
Oxides and hydroxides	2-6	100-800

Table 3. Soil orders and properties related to their clay mineralogical composition)Adopted from McLean, 1971).

ATRIBUTE	MOLLISOLS	ALFISOLS	ULTISOLS	OXISOLS
Type of clays	Illite, Mont.	Chloritized mont. and illite	Kaolinite, hydrous oxides	Hydrous oxides kaolinite
Crystallinity of clays	Cryst.	Cryst.	Cryst. and amorph.	Amorph. and cryst.
Ion exchange capacity	High cation	High cation	Low cation	High anion low cation
Ca & Mg saturation	Rel. high	Medium to low	Low	Very low
P fixing capacity	Low	Med.	High	Very high
K release tendency	High	Med.	Low	Low
Stability of soil structure	Excellent	Good to fair	Fair to poor	Good to excellent

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HYSICAL PROPERTIES OF SOILS [1/]

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Soils in their natural state are characterized as a three-phase system of solid, liquid and gas. The solid component is composed mainly of organic matter and inorganic particles varying in size, shape and mineralogical composition. For mineral soils the inorganic component constitute at least 80% of the total mass or weight of solids as opposed to organic soils, like peat and muck, which contain more than 20% organic matter. Because of infinite variations in sizes, shapes and orientation, the mutual arrangement of the solid particles determines the geometry and characteristics of the spaces or interstices formed between the particles. These spaces which are interconnected and having enlarged portions (caverns) interlinked with narrower portions (necks) are referred to as pore spaces in which the water and gas components are transmitted or retained.

The water in the soil which is commonly referred to as soil moisture contains dissolved substances so that it is also called soil solution. Soil air is actually a mixture of gasses similar to that of the atmosphere containing primarily nitrogen, oxygen and carbon dioxide. Due to root respiration and organic matter decomposition soil air is richer in carbon dioxide than atmospheric air. Since water and air are situated in the pore spaces their respective amounts in the soil at any given time vary inversely with the other. In a submerged

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paddy field all pore spaces are filled with water but negligible volume of air.

Volume and Mass Relationship of Soil Constituents

Under natural conditions. the soil constituents stronglv interact with each other so that it is difficult to define physically each phase independent from the other. However, for the sake of expressing quantitatively their proportions and in defining some basic soil physical properties, the mass and the coresponding volume of each soil constituent can be schematically considered independently as presented in Figure 1. The histogram in Figure 1. is divided in three sections; the lower section represents the solid phase, the middle section the liquid phase; and the top section the gaseous phase. The coresponding mass of each component are on the right-hand side; the mass of air (Ma), which is usually considered to be zero; the mass of water (Mw); the mass of the solids (Ms); and the total mass, (Mt); The volumes of the same component are indicated in the left hand side of the histogram; namely; the volume of air, (Va); the volume of water (Vw); the volume of pore spaces (Vp) in which Vp = Va + Vw; the volume of solids (Vs); and the total volume of the soil (Vt) in which Vt = Vp + Vs.

On the basis of the diagram in figure 1, the following basic soil physical properties which are related to the masses and volumes of the soil constituents are quantitatively defined.

(a) Soil densities. By definition density is the ratio of the mass or weight of an object to its volume. In soils there are two types of densities depending on which volume of the soil is being used in the calculation. If the total volume (Vt) is used, the density obtained is referred to as bulk density

(Db). On the other hand if the volume of the solids or particles alone is used, the density is called <u>particle density</u> (Dp). Using the diagram in figure 1 these densities are quantitatively defined as follows:

$$Db = Ms/Vt = Ms/(Va + Vw + Vs)$$

$$Dp = Ms/Vs$$

In most mineral soils the average particle density is about 2.65 gm/cm3. For a given soil, particle density is a fixed or stable property and does not vary significantly on soil management. It varies from soil to soil depending on their mineralogical composition and organic matter content. Soils high in iron minerals tend to have slightly higher values while soils with high organic matter content have lower values of particle density.

Bulk density is affected by the structural arrangement or packing of soil particles. Its value is sensitive to changes in the volume of pore space, hence the total volume of a given mass of soil. Lower bulk density values are associated with well-aggregated soils because aggregation usually leads to an increase in the volume of pore space (Vp) through an additional number and volume of large pore spaces developed in between soil aggregates. Because of its low density, organic matter affects directly bulk density. The effect of organic matter in promoting soil aggregation contributes indirectly to lower values of bulk density.

Any condition that brings about alteration of the arrangement of soil particles will cause change in the volume of pore space or total volume per unit mass of soil. Deterioration of soil aggregates resulting from continuous and improper cultivation of a soil leads to increase in bulk density. Cultivated and compacted soils generally have higher bulk density than their virgin soil counterpart.

It is also a common observation that fine or clay textured soils have lower bulk densities than coarse or sandy soils. Although less apparent when randomly arranged plate-like clay particles tend to produce larger amount of pores than the spheriodal coarse particles. Furthermore, clay content is positively correlated with improved degree of soil aggregation.

Certain pedogenic processes also result to variation in bulk densities among the horizons of a soil profile. The movement of fine or clay particles from the A horizon and their subsequent accumulation in the macro pore spaces of the B horizon causes higher bulk density in the subsoil. Swelling and shrinkage of some clay minerals decreases and increases, respectively, the bulk density of a some soils depending on their moisture content.

(b) Porosity (N). Porosity is the proportion of the total pore space volume (Vp) to the total volume of a soil (Vt). Expressed in percent, total porosity N is given as

$$N = \frac{Vp}{Vt} \times 100$$

It is very difficult to measure directly Vp, hence, in practice total porosity is calculated using the data of bulk density (Db) and particle density (Dp). The relation used is given as:

$$N = (1-Db/Dp) \times 100$$

The above equation implies that since Dp is almost constant in soils, total porosity increases as bulk density decreases. Bulk density is therefore often used as an index of total porosity changes in comparable soils. Porosity depends both on texture and structure. Factors tending to promote

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stable soil aggregation increase total porosity. On the other hand improper and frequent cultivation may enhance faster decline of soil organic matter and destabilizes the soil aggregates which may adversely affect total porosity.

(c) Soil Moisture Content. The moisture content of the soil can be expressed in various ways. The most commonly used indexes are the following.

1. Gravimetric moisture content (Θm). This is the mass of water relative to the mass of dry soil. The term "dry soil" refers to a soil dried to equilibrium in an oven at 105 ^{o}C, hence, the mass of "dry soil" which is measured gravimetrically is referred to as "oven dry mass" or "oven dry weight" of the soil. The mass of water (Mw) is the difference between the gravimetrically measured weight of a soil sample at moist and oven dried moisture conditions. With reference to figure 1 gravimetric moisture content is calculated as:

$$\Theta w = Mw/Ms \quad ; \quad gm/gm$$

2. Volumetric moisture content (Θv). This expansion of water content is represented as:

$$\Theta v = Vw/Vt \quad ; \quad cm3/cm3$$

Since in most cases moisture content determinations utilized disturbed soil samples, the total volume of the soil (Vt) is not measurable, hence, an alternative formula is used in the computation of volumetric moisture content given as;

$$\Theta v = \Theta w \times Db/Dw$$

In such a case, it is necessary to determined both the gravimetric moisture content (Θw) and bulk density (Db) of the soil. Dw is density of water which is usually equal to 1 gm/cm3.

3. Height or depth of water in the soil (Hw). This expression of water content is used more often by engineers

because it is more adaptable to the computation of water quantities added and substracted to soil by irrigation or rain and by evapotranspiration or drainage, respectively. The above water quantities are often expressed in terms of cm height of water. Height of water (Hw) in the soil is calculated using the formula

$$Hw = Ov \times Ht$$

Where Ov is the volumetic moisture content and Ht is the total height or depth of soil in question.

Soil texture

The "texture" of a material is an expression of its coarseness or fineness when the material is rubbed in between the finger. A soil maybe coarse, medium or fine in texture depending upon the dominant size or size range of the particles. Quantitatively, soil texture refers to the relative proportions of various inorganic particles belonging to a particle size range in a given soil. The most commonly used three size ranges of soil separates are the sand, silt and clay. Two classification scheme of grouping soil particle sizes are the International Soil Science Society (I.S.S.S.) and the United States Department of Agriculture (U.S.D.A.) classifications. Table 1 presents the details of these schemes.

Table 1. Particle classes and their size ranges.

Separates	Diameter (mm)	
	U.S.D.A.	International
Sand	2 -0.05	2 -0.02
Very coarse sand	2 -1.0	-
Coarse sand	1 -0.5	2.0-0.2
Medium sand	0.5-0.25	2.0-0.2
Fine sand	0.25-0.10	0.2-0.02
Very fine sand	0.10-0.05	-
Silt	0.05-0.002	0.02-0.002
Clay	<0.002	<0.002

Sand, the soil separate with largest particle size range, possesses very low specific surface (surface area per unit quantity), hence, have negligible influence on the fertility, chemical reactivity and water retention ability of soils. However, this separate provides large pore spaces that facilitates movement of air and water.

Clay separates, due to smallness in size and plate-like shape, has tremendous amount of specific surface area. As a result this separate imparts significant influence in controlling properties and behavior of soils. Clay retains high amount of water and plant nutrients in its surfaces which can later be realeased and taken up by plant. Placticity and stickness of a moist soil is also dependent upon the amount and kind of clay present.

The silt particles have properties in between the two extremes of size.

Soils contain varying proportions of the three soil separates. Depending upon the relative proportion of sand, silt and clay content, soils are classified into textural classes. Classifying soils according to textural classes requires the used of standard technique of sieving and of sedimentation of mechanically and chemically dispersed soil samples. The relative amount of the three separates expressed in % sand, % silt and % clay of a soil sample are referred to a textural triangle presented in figure 2 where the textural class is identified. The triangle identifies twelve textural classes which can, for convenience still be classified into broader classes.

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(a) Clay group or fine-texture soil

1. Clay
2. Silty Clay
3. Sandy Clay

(b) Loam group

Moderately fine-textured soil

1. Clay loam
2. Silty Clay loam
3. Sandy Clay loam

Moderately coarse-textured soil

1. Silt Loam
2. Loam
3. Sandy Loam

(c) Silt

(d) Sand group or coarse-textured soil

1. Loamy sand
2. Sand

In general, fine-textured soils are more fertile than coarse-textured ones because of their ability to hold and supply plant nutrients. Because of the dominant micro pore sizes, the water holding capacity of fine-textured are greater than the coarse-textured soil. But soils with high clay content becomes very hard when dry and very sticky when wet. Tillage therefore would be difficult to perform at certain moisture contents. When tillage operations are done on a fine-textured soil at drier moisture contents "heavy effort" is needed. On the other hand, at higher moisture content they become sticky and plastic.

Loam is a soil that exhibits the inherent properties and characteristics of the three separates (sand, silt and clay) in almost equal proportion. It is mellow with some gritty feel, fairly smooth and only slightly plastic and slightly sticky when moist. It is moderately well-aerated neither easy nor difficult to till and is preferred for upland crops agriculture.

Sands or coarse textured soils are the exact opposite of the clays in characteristics; being droughty, less fertile, well aerated, non-plastic, non-sticky and easy to cultivate.

Soil Structure

In their natural occurrence, the solid particles particularly those in the fine to moderately-fine textured soils exist not as individual units but as clusters of particles held together by binding or cementing agents (humus, oxides of iron and aluminum, and colloidal clays). These clusters of individual particles are called peds or aggregates which are in turn held together by weaker binding forces to form the soil mass. The pattern of spatial arrangement of individual soil particles into aggregates and the aggregates into the soil mass is referred to as soil structure.

In field examination, qualitative description of soil structure includes the grade or relative durability of the peds, the class or size of the peds and the type or shape and arrangement of peds. The folowing schemes are used to describe this feature

(a) Grade

0. Structureless - no observable aggregation

1. Weak - poorly formed, non-durable indistinct peds breaking into a mixture of a few entire and many broken peds and much unaggregated materials.

2. Moderate - well formed, non distinct in undisturbed soil, that breaks into many entire and some broken peds but little unaggregated materials.

3. Strong - durable, distinct peds, weakly attached to each other that breaks almost completely into entire peds.

(b) Class (size of peds)

	Platy	Prismatic and Columnar	Blocky and Subangular Blocky	Granular and Crumb
1. Very thin or very fine	<1 mm	<10 mm	<5 mm	<1 mm
2. Fine or thin	1-2	10-20	5-10	1-2
3. Medium	2-5	20-50	10-20	2-5
4. Coarse or thick	5-10	50-100	20-50	5-10
5. Very coarse or very thick	>10	>100	>50	>10

(c) Type (shape and arrangement)

1. Platy - limited vertical axis, arranged around a horizontal plane.

2. Prismatic - horizontal axis shorter than vertical, arrange around a vertical line, well defined vertical faces and angular vertices.

3. Columnar - like prismatic except that vertice with rounded caps.

4. Blocky - blocklike having plane or curved surfaces accommodated to the faces of surrounding peds.

   i. Angular blocky - faces flattened, vertices sharply angular.

   ii. Subangular blocky - mixed rounded flattened faces, many rounded vertices.

5. Spheroidal - spheroids or polyhedrons with plane or curved surfaces, slight or no accommodation to the faces of surrounding peds.

   i. Granular - relatively non-porous peds
   ii. Crumb - porous peds

Soil structure is usually evaluated quantitatively using a number of indices. Some of these are bulk density, porosity, pore-size distribution and soil aggregation. The degree of soil aggregation which includes stability and size distribution of aggregate can be evaluated by subjecting aggregated soil sample to slaking action of water.

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Since the above indices directly or indirectly measure the characteristic of the pore space, and the arrangement, size and position of the individual solid particle and the peds, soil structure influences various processes affecting the movement and retention of water and air in the soil such as infiltration, percolation, capillary rise, and aeration. It influences mechanical impedance to root growth. Also, it serves as an important basis in differentiating soil bodies.

<u>Soil Consistency</u>

Soil consistency signifies the manner in which the forces of cohesion and adhesion acting within the soil are manifested at various moisture contents. Thus a cohesive soil, e.g. fine-textured soil, when dry is hard and behaves like a solid when moist is friable and behaves like a semi-solid tha crumbles into peds, when wet is plastic and sticky, and whe saturated is viscous and behaves like a liquid.

Cohesion forces play an important role in the consistency transformation of a wetting previously dry soil as presented in Figure 3. In Fig. 3 the cohesion within the aggregate (intra-aggregate) and between aggregates (inter-aggregates) is recognized which influences the consistency of the soil mass. Intra-aggregate cohesion is maximum at the very low moisture contents due to attraction forces between primary particles which are fully developed because of minimum separation between them. As more water is imbibed in between the plate-like solid particles cohesion decreases, individual aggregate becomes soft or even swells depending upon the nature of clay and amount of binding agents.

Interaggregate cohesion shows a different pattern with increasing moisture content. At very low moisture content total cohesion between the aggregate is very low due to very little contact between aggregates. With increasing moisture content the aggregates swell causing confronting surfaces to move closer together and water surrounding [illegible] gregates provides pulling force, so that this kind of [illegible] increases with increasing water content reaching a maximum value at sticky point where soil mass adheres to the surfaces of other bodies such as plow, disc and other implements. With more water, the water films coalesce and the pulling force dissipates, while the aggregate are pushed farther apart thus cohesion decreases with further increase in water content.

There are methods employed to follow soil consistencies. The Atterberg limits, namely, liquid limit, plastic limit and shrinkage limits have gained acceptance among soil engineers in describing the physical state of the system. The limits are defined by the water contents required to produce specified degrees of consistency that are measured in the laboratory.

Liquid limit (LL) approximates the minimum moisture content at which the soil may exhibit a ten[illegible] to undergo liquid flow when subjected to some form of str[illegible] moisture content greater than LL the soil becomes viscous and acts like a liquid. Plastic limit (PL) estimates the minimum moisture content at which a soil may undergo deformation without rupture, so that at moisture contents between LL and PL the soil behaves like a plastic. It is within this range of moisture contents that the soil possesses highest degree of stickiness, plasticity and compactness. The difference between the moisture contents at LL and PL is known as plastic number or index. Plastic number as well as the other Atterberg limits depends on the amount and mineralogy of the clay, and the organic matter content of the soil. Thus, with known clay and organic matters contents plastic number sometimes is used to guess the mineralogy of the soil.

For a shrinking system, as in the cases of many clay soils, drying or removal of water will cause a reduction in soil volume. As water is continously removed from the soil, eventually a point is reached where further shrinkage stops. At this point of moisture content, the soil is said to have reached the <u>shrinkage limit (SL)</u>.

As also shown in figure 3, tillage operations are best done at moisture contents between SL and PL when the soil is friable. Minimal energy is required to prepare the land for seedbed. Below this range the soil is hard and will require very high amount of energy or work to pulverize the soil. At moisture content above this range or between PL and LL the soil is plastic, soil structure is easily destroyed, the soil is easily compacted and easily sticks to the plow or other farm impliment. Above the LL, the soil is easily puddled with maximum destruction of soil structure.

Consistence when moist is normally used in field description of this property. At this moisture condition most soil materials show a form of consistencies characterized by (a) tending to break into smaller masses rather than to powder, (b) some deformation to rupture, (c) absence of brittleness, (d) ability of the materials to cohere again when passed together. To evaluate consistency, a moist soil mass is taken with the hand and the following may be descriptive:

0 - Loose: Noncoherent

1 - Very friable: soil material crushes under very gentle pressure but coheres when pressed together.

2 - Friable: soil material crushes easily under gentle to moderate pressure between thumb and forefinger, and coheres when pressed together.

3 - Firm: Soil materials crushes under moderate pressure between thumb and forefinger best resistance is noticeable.

4 - Very firm: Soil material crushes under strong pressure: barely crushable between thumb and forefinger.

5 - Extremely firm: Soil material crushes under very strong pressure, cannot be crushed between thumb and forefinger and must be broken apart bit by bit.

Consistence when wet is described according to the degree of plasticity and stickiness. Plasticity is the ability to change shape continuously under the influence of an applied stress and to retain the impressed shape on removal of the stress. Stickness is the quality of adhesion to other object or material. The consistence of soil material when dry is characterized by rigidity, brittleness, maximum resistence to pressure, more or less tendency to crush to a powder or to fragments with rather sharp edges, and inability of crushed material to cohere again when pressed together.

Soil Color

Soil color is a physical characteristic that is most obvious when one performs morphological description. It is useful in soil identification specially when combined with other soil properties. There are distinct ranges of soil color that can be associated with the dominance of a particular soil material or chemical changes that has taken place in the soil. For example, generally, dark-colored soils are relatively higher in organic matter than light-colored soils, although the dark-color may be due to the presence of high amount of compounds of manganese and iron. Red color is generally related to unhydrated iron oxides and usually indicate good drainage and good aeration. Dark gray with yellowish red mottles is typical of the plow layer of paddy fields indicating poor drainage and chemical reduction.

Soil colors are conveniently noted using a color chart with Munsell notations arranged to provide the hue, value, and the chroma. The hue refers to the dominant wavelength of the light or spectral color. Value refers to the relative lightness of color and is a function of the total amount of light while chroma is the relative purity or strength of the spectral color and increases with decreasing grayness.

In the Munsell color chart the symbol for hue refers to the color of the rainbow such as R for red, YR for yellow red, and Y for yellow where each letter designation is preceded by numbers from 0 to 10. As the number increases, the hue becomes more yellow and less red under each letter designation. Value consists of numbers 0 for absolute black to 10 for absolute white whereas chroma consists of 0 for neutral grays and increases to about 20. For instance, a soil sample placed under 5YR and matched at 5/6 is described as yellowish red (5 YR 5/6).

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Flaniaghdan's Pxxx

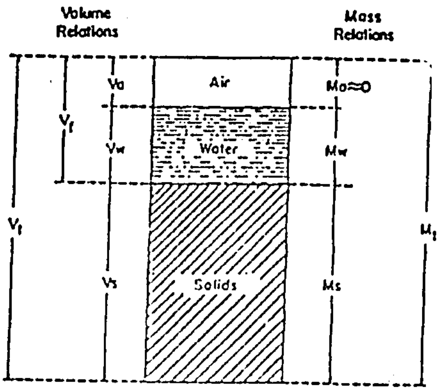

Fig. 1. Schematic diagram of the soil as a three-phase system. (Hillel, 1971)

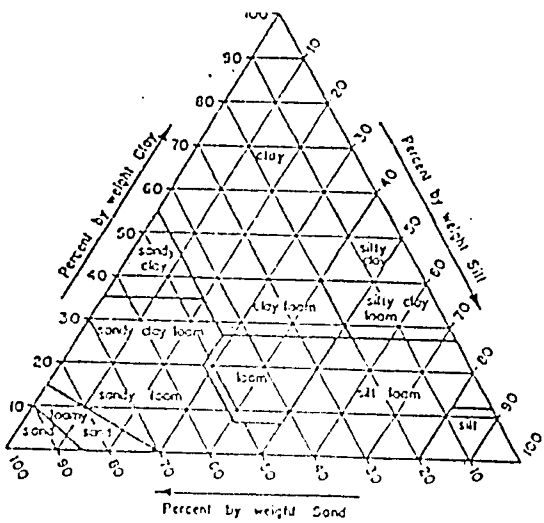

Fig. 2. Textural triangle, showing the percentages of clay (below 0.002 mm), silt (0.002-0.05 mm), and sand (0.05-2.0 mm) in the basic soil textural classes. (Hillel, 1971)

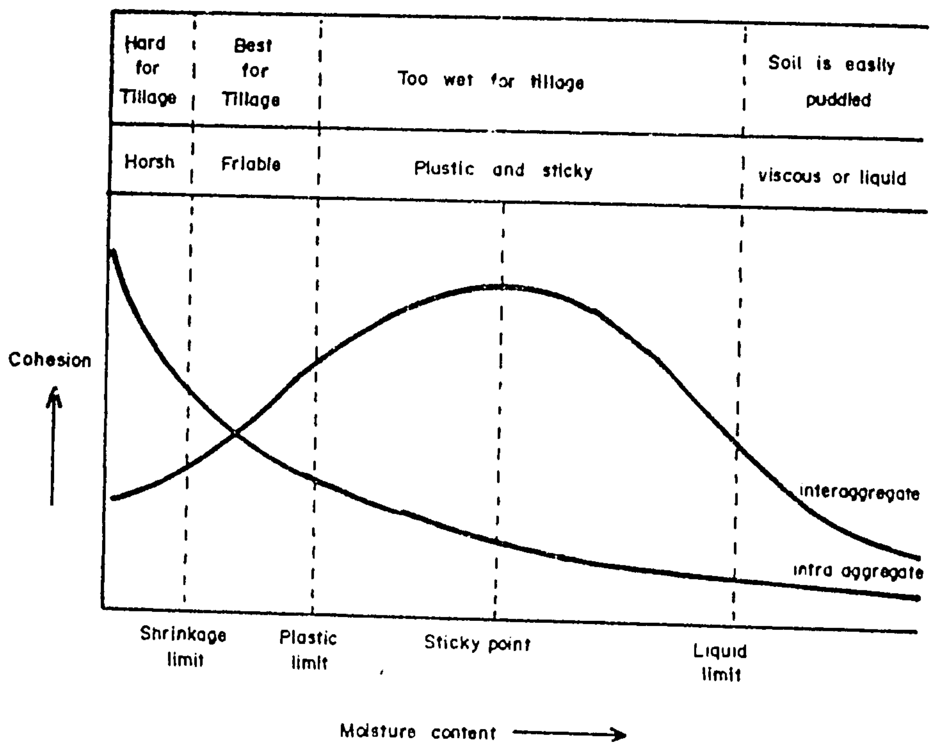

Fig. 3. Soil consistency, consistency indices, tillage properties in relation to interaggregate and intra-aggregate cohesion. (Adapted from Briones, 19[illegible]9)

SOIL FERTILITY AND MANAGEMENT IMPLICATIONS OF SOIL TAXONOMY[1/]

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SUMMARY

The potential of Soil Taxonomy as a powerful tool for predicting and locating appropriate crop environments is just starting to be recognized. The apparent advantages of using this systems in assessing soil fertility and management requirement of crops is that it minimumizes the conduct of site-specific trials and facilitates transfer of experience acquired from similar soils of different location once they are classified according to this sytem. As a medium of communication among soil researchers and soil scientists, Soil Taxonomy offers the rapid sharing of technology and the resulting transfer of this technology to where it is most needed.

INTRODUCTION

Conventional methods of assessing soil fertility by means of soil tests and a series of site-specific field trials place a heavy demand on time and resources. Fertilizer recommendations for specific crops can be made with confidence only after these trials are repeated over several seasons and locations. Information from these trials then becomes the basis for extrapolating crop performance to other areas. There has been no systematic way of transferring soil fertility and management information to new areas except on the basis of local experience gained from the above methods. This may explain why failures of agrotechnology transfer have become a common occurrence when foreign experts are hired to make recommendations for other countries consulting local experts.

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It is now possible to make generalizations about the soil fertility and management requirements for a given crop on the basis of soil classifcation using Soil Taxonomy (Soil Survey Staff, 1975). The Benchmark Soils Project (In Press) has demonstrated that soil-based agrotechnology can be transferred on the basis of similar soils. This hypothesis was tested by the project through a series of soil fertility experiments in five countries and 24 experimental sites representing a network of three soil families. The tests have shown that similar crop performance can be predicted if the soils belonged to the same soil family as defined in Soil Taxonomy. The soil family category was used to group similar soils.

This concept of transferring agrotechnology on the basis of similar soils could revolutionize the making of generalizations about the technology requirements of soils. It woild also make the transfer process a rational and scientific effort. This means that a newcomer to an area can make generalizations and recommendations with very high probability of success in matching the crop to the soil environment without relying so much on local experience. This would mean that site-specific trials can be minimized or totally eliminated as long as similar experience has been obtained elsewhere on similar soils.

This paper will illustrate how Soil Taxonomy can be used as a tool to systematize existing methods of assessing or making predictions on the soil fertility and management requirements of certain crops.

EXTRACTING SOIL INFORMATION FROM TAXONOMIC NAMES

Soil Taxonomy as a classification system was devised to meet the purposes of soil survey. Soil surveys are conducted to make an inventory of soil resources for the sole purpose of making generalization or predictions about the agricultural and engineering uses of these resources. Soils thus classified are shown on a soils map which can be produced in various scales depending on the intended use.

The power of Soil Taxonomy as a utilitarian method for classfying soils lies in its nomenclature system. Names given to soils convey meanings that are related to soil properties. These names are grouped into six hierarchial categories, the highest category being the order, then followed by suborder, great group, subgroup, the soil family and the soil series categories. A syllable or group of letters or words from the name of the higher category is always carried down through the lower categories until the soil family. (The soil series name is not derived from the nomenclature systen and conveys no meaning in relation to soil properties.) In essence, this system enables a person to identify or remember which category that a soil name belongs to along with those properties which are associated with that name in a particular category. Information which can be extracted from a soil name increases as one goes down from the higher to the lower categories. For example, a greater amount of information is provided at the soil family category than at the subgroup level. This is illustrated in the following examples which were the soil families used by the Benchmark Soils Project:

1. Soil family names: thixotropic, isothermic, Hydric Dystrandepts

   Interpretations:

   Thixotropy is a property of gels and in soil this name usually applies to gel-like amorphous materials. This means that a soil in order to be thixotropic must have abundant amorphous materials. Soils with such property are usually deficient in phosphorus and large applications are required to satisfy the phosphorus-fixing capacity of these soils.

   Isothermic describes a soil temperature range of 15-22 degrees Celcius measured at 50-cm depth. The iso syllables indicate that the mean annual summer temperatu does not vary by more than 5 degrees Celcius from the me annual winter temperature.

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Hydric was derived from the Greek word hydor, meaning, water Hydric, therefore, as used in Soil Taxonomy means a condition of water abundance. The soil may be interpreted as being subject to high rainfall throughout most of the years. If irrigation were required it would only be supplemental.

Dystrandept can be separated into 3 groups of syllables. Dystr comes from the word dystrophic meaning infertile. And is a name derived from Ando, which connotes volcanic ash soils. The last group of letters, epts is from the soil order name, inceptisols. Incepticols are soils that are just beginning (from inceptum) to show horizon differentiation. Andept is a suborder name. Soils under this category must have a bulk density of $<$ .85 g/cc. These are light soils with very good physical properties. Since they are thixotropic they are difficult to compact and could dry irreversibly into small aggregated particles. The internal drainage is good and very suitable for minimum tillage-type of farming. Being a Dystrandept it is almost devoid of most macronutrients. This first example of a soil name can be interpreted as a young soil derived from volcanic ash with high P-fixing capacity. Crops that can tolerate the cold temperature regime should do very well in these soils such as the leafy brassicas.

All the above information are condensed in the soil name consisting of only four words! A second example follows

2. Soil family names: clayey, kaolinitic, isohyperthermic, Typic Paleudults

Interpretations:

This is a soil with more than 35% clay, kaolinitic mineralogy, and a soil temperature regime greater than 22 degree Celsius. It is a typical representative of the great group, Paleudult. It is also an Ultisols (ult from ultimus, meaning last), with a wet (from the Latin udus, humid) moisture regime, and relatively old (Pale is from the Greek word paleos, old). Being an old soil implies it has < 10% weatherable minerals in its subsoil which are the primary source of soil nutrients (bases). This also means that this soil is relatively infertile because of this lack of nutrient source. By definition, Ultisols have reached the ultimate in the weathering process - highly leached in bases and as a consequence, have very low base saturation and very high exchangeable aluminum which makes these soils very acid. These are common soils in the humid tropics such as those found in Sumatra, Indonesia. The application of lime is one of the needed practices to enhance the production of most annual food crops. Under conditions of limited fertilizer resources the cropping system that has evolved in these soils is the planting of perennial crops with very deep root systems that can forage for nutrients over large soil volumes. Most of the tree crops belong to this cropping system along with some perennial vines and shrubs.

SOIL FERTILITY AND MANAGEMENT INDICATORS IN SOIL TAXONOMY

Soil Taxonomy, as a quantitative system of soil classificat: is based on the physical, chemical, and mineralogical properties o: soils. Long-term weather data are also used to evaluate the temperature and moisture regimes of soil families. The measured properties are used to place the particular soil in a given catego: or taxon. The following discussions shall illustrate some of thes indicators.

EXTRACTABLE BASES

Potassium, calcium, and magnesium are the extractable bases that are of importance to plant growth. These chemical elements are measured in addition to sodium to determine base saturation, which is percentage of the cation exchange capacity. Base saturation is used to separate and designate certain diagnostic horizons which place certain soils in their various orders. It is also used to separate soils under the same suborder in their great group category. In general, soils with high base saturation (>50%) have high native fertility such as the Mollisols and Alfisols. Those with low base saturation (Oxisols, Ultisols, Spodosols) have low native fertility.

EXTRACTABLE ALUMINUM

As weathering progresses more and more of the extractable bases are leached and a higher concentration of soluble aluminum results. In tropical soils that are highly leached in bases such as the Oxisols and Ultisols, it is the extractable aluminum that poses concern among crop scientists because of its toxic effect on plants and resulting immobilization of phosphorus. Since the pH of these soils is also low, other elements like iron and manganese also become abundant sometimes at toxic levels. Toxicity of these elements has been found in certain crops but the problems they pose to crop production are not as critical as aluminum. Liming rates are not based on conventional pH curves since these acid tropical soils, with their high buffering capacity would require tremendous amounts of lime to register any significant change in pH. Rather, the percent extractable aluminum saturation (> 30% of effective cation exchange capacity; BSP, 1982) is a better index of liming than pH, per se. Generally, for most crops a factor of 1.5 to 2 times the extractable aluminum provides the amount of lime that is sufficient to neutralize the extractable aluminum and also provides sufficient calcium for crop nutrition, irrespective of the pH. The Benchmark Soils Project (1978) has confirmed this fact and found that even soils with low pH (5-5.5) do not respond to liming as long as the extractable calcium in the soil is high and the extractable aluminum is low. In Soil Taxonomy, KCl-extractable akuminum is an important parameter in identifying certain subgroups in most of the soil orders.

HORIZONS OF MINERAL OR CHEMICAL CONCENTRATION

Some soil family name designations or descriptions indicate horizons in which certain soil minerals or chemicals are concentrated such as gypsum, carbonates, sulfur, iron, sodium, oxides, etc. One, therefore, can easily identify certain soil attributes or constraints which can be avoided or selected for crop production purposes.

OTHER INDICATORS

Soil moisture, soil temperature, mineralogy, particle-size distribution and physical features such as hardpans or hardened materials are the other important indicators which can be extracted from the soil name.

Soil moisture conditions which are dominant in a particular soil are generally incorporated in the suborder category. Aridisol, is an exception a soil order of the arid environment. Particle-size distribution, mineralogy, and soil temperature are used as descriptive words or phrases in the soil family name.

Dominant physical features such as duripans, plinthite, fragipans, and pyroclastic materials are usually incorporated in the great group category, e.g., Durixeralfs, Plinthaquepts, Fragihumods, Vitrandepts, etc. They are sometimes found as descriptive words in the subgroup name, e.g. Duric Eutrandepts or Plintic Tropaquepts.

Some technical background and knowledge about soils and crops are required to extract information from taxonomic names. This is especially true with implicit information. A person, however, need not be a specialist in Soil Taxonomy to make these interpretations. Soil fertility and management specialists should be able to use the system as a tool for planning crop production strategies which can later be communicated to planners and policy makers.

A suggested method for learning to interpret soil taxonomic names is to start at the order level and associate these names with

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their dominant features or marks in the environment in which they were classified (See Table 1). Next, learn the nomenclature system and start adding formative elements to the order name which can be associated to soil properties (See Table 2). And then proceed down to the lower categories until the family category where the description becomes more explicit. The task is not to classify soils (that's the job of the soil taxonomist) but to be able to make interpretations from taxonomic names.

The system is easy to learn if the desired interpretations are associated with specific uses. This is reinforced by knowing the crop requirements for certain crops and matching these requirements with the soil environment which can be extracted from the soil name.

For example, for optimum growth of many tropical leguminous trees, the following are required: a warm environment, soils with adequate calcium for proper nutrition, and nonlimiting water supply throughout most of their entire growth. Using Soil Taxonomy, one can pick out soils having an isohyperthermic temperature regime ($>$ 22 degrees Celsius), a udic or humid moisture environment and a high base saturation. There are two soils in the soil order category that have high base saturation, the Mollisols and Alfisols. In the Mollisols, the Udolls have a udic moisture regime; in the Alfisols, the Udalfs should provide the same moisture conditions. Soil families with isophyperthermic temperature regime should complete the necessary requirements of these trees.

Table 1. Categories in Soil Taxonomy and their dominant features (Cagauan, Tsuji, and Ikawa, 1982)

SOIL CATEGORY	NUMBER OF TAXA	DOMINANT FEATURES
Order	10	Presence or absence of different kinds of soil horizons, which are related to soil-forming processes.
Suborder	45	Presence or absence of properties, such as those associated with moisture, parent material, or vegetation.
Great group	187	Similarity of horizons, base status, soil climatic parameters, and presence or absence of different kinds of soil layers or pans

Table 1 (Continuation)

SOIL CATEGORY	NUMBER OF TAXA	DOMINANT FEASTURES
Subgroup	990	Differentiation according to a central concept or gradation to other great groups, suborders, and orders.
Family	5,603	Information on the particle size (textural) class, mineralogy, soil temperature class, and other properties such as soil depth and consistency.
Series	12,002 (U.S. only)	Information on the kind and arrangement of horizons with morphological, chemical, and mineralogical properties.

Table 2. Examples of taxonomic nomenclature that are related to soil fertility and management

FORMATICE ELEMENT	DERIVATION	SOIL NAME	SOIL CATEGORY	INTERPRETATION OR MEANING OF SOIL NAME
Aqu	Aquic, wet	Aqualf	Suborder	Wet Alfisol
Dystr	Dystrophic fertile	Dystrandept	Suborder	Low base saturation inceptisol derived from volcanic ash
Ert	Latin verto, to turn	Vertisol	Order	Soils that shrink on drying and swell on wetting
Eutr	Eutrophic, fertile	Eutrustox	Great Group	Dry oxisol with high base saturation
Hum	Humus	Humult	Suborder	Humus-rich Ultisols
Pale	Greek paleos, old	Palehumult	Great group	Highly-leached humus-rich Ultisols
Psammi	Greek psam-mos, sand	Psamment	Suborder	Sandy Entisols
Ud	Latin udus, humid	Udult	Suborder	Humid Ultisols

Results from the Benchmark Soils Project experiments on five species of these trees confirm these requirements. Growth measurements one year after planting showed that all five species planted in the Ultic Tropudalf (Davao, Philippines) registered the best growth when compared to the same tree species grown in three other soil families. These measurements are summarized in Table 3.

It is quite apparent that the Typic Tropudalf meets all the above crop requirements. The Tropeptic Eustrustox site (Waipio, Hawaii), although it has a high base saturation and warm teperature regime, lacked the necessary humid condition for favorable tree growth. The Hydric Dystrandept site (Niulii, Hawaii) has a cool temperature regime which limited tree growth although calcium and base saturation appeared

Table 3. Growth Performance of Five Tropical Leguminous Trees (Benchmark Soils Project, In Press)

SOIL FAMILY[1]	TEMPERATURE REGIME	MOISTURE REGIME	SURFACE FERTILITY		AVERAGE TREE HEIGHT AT ONE YEAR, METERS				
			Ca m.e./100g	BS%	LEUCAENA LEUCOCEPHALA	LEUCAENA DIVERSIFOLIA	SESBANIA GRANDIFLORA	CALLIANDRA CALOTHYRSUS	ACACIA AURICULIFORMIS
A	> 22°C	Udic	9.34	82	7.3	7.9	6.0	4.8	4.8
B	> 22°C	Udic	2.28	24	2.9	3.1	2.0	2.3	2.5
C	15-22°C	Udic	15	7.93	2.0	3.1	1.5	2.3	1.0
D	> 22°C	Ustic	6.52	66	4.5	4.9	3.1	2.1	2.1

[1]A - very fine, halloysitic, isohyperthermic, Ultic Tropudalfs (Davao, Philippines)
B - clayey, kaolinitic, isohyperthermic, Typic Paleudults (Nakau, Indonesia)
C - thixotropic, isothermic, Hydric Dystrandepts (Niulii, Hawaii)
C - clayey, kaolinitic, isohyperthermic, Tropeptic Eutrustox (Waipio, Hawaii)

adequate. The Typic Paleudult site (Nakau, Indonesia) has the lowest calcium content which might have limited tree growth also, although the other crop requirements have been sufficiently met. The above example illustrates the importance of matching crop requirements to the environment.

SOIL-BASED AGROTECHNOLOGY TRANSFER

The ability to interpret soil names for specific uses leads us to most significant contribution of Soil Taxonomy the transfer of knowledge or experience on the basis of soil classification. The Benchmark Soils Project (1978, 1979, 1982), a research project of the United States Agency for International Development, implemented by the Universities of Hawaii and Puerto Rico, was the first research endeavor which tested the value of soil classification as a means to transfer soil-based agrotechnology. A complete description of this project was presented earlier in this workshop (Cagauan, 1984a, 1984b). The findings from this project will have far-reaching effect on the use of Soil Taxonomy as a tool to make predictions about crop performance and the associated requirements to achieve that performance.

As stated earlier in the above examples, the soil family names contain most of the information required to determine the suitability of a given location for crop production. It is, therefore, desirable that soils be classified to the soil family category. This does not mean, however, that an assessment of crop performance cannot be made without classifying soils in their family category. Higher categories contain information which can also be used for such purpose although, as stated earlier, other information are lacking such as particle-size distribution, mineralogy, and temperature regime.

When scientists or researchers of different nations talk about transfer of agrotechnology, Soil Taxonomy can provide the common medium of communication in which to identify crop performance under a given set of environments. Having a common medium of communication can accelerate the transfer of agrotechnology by the rapid sharing of knowledge and experience about soils.

Soil Taxonomy can also provide the basis for solving common soils problems through the establishment of benchmark sites that are classified according to this system. A network of these benchmark sites should allow the grouping of areas with similar soils, crops, and problems. Researchers working in concert through such a network should be able to find solutions to agronomic problems much more thoroughly and effciently than working in isolation from one another. Eventually, crop simulation models may be developed to deal with specific soil constraints which can predict crop performance under any conditions without resorting to site-specific field experimentation. This is one of the goals of another AID project called the International Benchmark Sites Network for Agrotechnology Transfer (IBSNAT).

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AGRONOMY OF COCONUTS[1/]

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1. INTRODUCTION

The coconut is grown for a variety of uses but it is its fruit or nut which has the highest economic value. The lauric (C_{12}) acid-rich oil is extracted from the dried meat (copra).

In the American, European and Japanese markets, coconut oil, like palm oil, palm kernel oil and soya oil, serves as a raw materi for the manufacture of margarine and other food fats (Das, 1985). The coconut and its oil will continue to be important to economies of the producing countries like the Philippines, Indonesia, India and Sri Lanka. The development of high yielding coconut hybrids has considerably increased the yields and reliability of coconut palms, and certainly this crop holds great promise both as a food crop and powerful energy supplier in the tropics. As a raw material for the manufacture of soaps and detergents, coconut would continue to be an important source.

The Philippines is the world's largest producer and exporter of coconuts. Coconut is grown in 58 out of the 74 provinces of the country and is a major crop in 35 of these. Moreover, 1/3 of the total population (54 millions) depend directly or indirectly from th coconut industry for their livelihood.

Generally, the coconut producing countries are located in the zone between 20°N and 20°S latitudes, and areas with a uniform rainfall distribution and low typhoon frequency or occurrence (0-10%) producing high yields. Specifically, the yield of the coconut crop i the resultant of the interaction of several factors: variety, soil, climate, pest and diseases and cultural management practices.

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This paper deals mainly on the crop and soil management of the coconut. In addition, fertilizer application is discussed to a great extent as fertilizer has been recognized to be a single important agricultural input that could bring immediate increase in yield.

2. CROP ESTABLISHMENT

Before starting a coconut farm/plantation, special attention should be taken to see that the climatic and soil conditions in the area are suitable for growing the crop. Suitable areas are those with: adequate rainfall (soil moisture throughout the year; elevation not higher than 600 m (above sea level); well-drained externally and internally, deep soil ($\leq$ 95 cm); adequate levels of nutrients.

2.1 Land Preparation

Techniques of preparing the land depends much on the topography of the land and its natural vegetation. On slopes or in places where erosion is great, it is advisable to sow a covercrop at the time of planting or even beforehand if possible. Construction of terraces following the contour lines is a very tedious task but will prove valuable in the long run.

Bare soil that has been under other crops needs no special preparation in advance of coconut field-planting. For savannah or forest areas, the work is done manually by chopping down trees and bushes and hoeing the grasses. However, mechanization is a necessity when rhizomatous grasses like cogon (*Imperata cylindrica*) covers the ground entirely. Removal of grasses must be pursued to the end or it will rapidly re-grow particularly in areas with good rainfall distribution.

In a moderately thick vegetation, tilling and piling the woods into heaps go on simultaneously. After a few weeks of drying out, woods are burned. When mechanical preparation is employed, care should be taken not to invert or bury the humus-bearing top soil, as this would seriously distrurb the biological equilibrium.

2.2 Density and System of Planting

Many old coconut farms in the Philippines belong to small family properties, in which owners often plant at random without much regard to regular spacing. It is very common to see mixed plantings of coconut and other crops. The tendency towards over planting is due to the fact that valuation of land, especially in Southern Luzon, is based on the number of trees planted in a given area rather than on yield per unit area.

In deciding the proper spacing, some important factors have to be considered. One is that adequate room should be provided for proper development of the roots. It is reasonable to consider that depending upon the soil, climatic conditions, and variety, there exists a definite number or plants per hectare which will give maximum yields. If the stand falls short of the optimum, production is diminished because full advantages was not taken of the available area. On the other hand, if the stand is excessive, the yield will also be diminished owing to over crowding and consequent intense competition between palms for plant food, moisture and sunlight. Under this condition, the tendency of the palm is to grow tall and lanky in their struggle for sunlight resulting in considerable loss of energy in producing long trunks at the expense of yield.

Four systems of planting: square, triangular, rectangular and quincunx are followed, but the first two are the most common. In the <u>square</u> system, the palms are set at fixed equal distances at the corners of each square, the distance between palms in each row and the distance between adjacent rows being the same. In the <u>triangular</u> system, palms are set at fixed distance at the corners of an equilateral triangular. In this sytem, about 15% more palms can be accommodated per unit area. In the <u>quincunx</u> system, seedli[illegible] [illegible] the center of each square of old palms. This method is used only for replanting old coconut plantations where the trees will be removed as soon as the new seedlings are established. In the rectangular system, rows cut at right angles to one another but the distance between the palms in the row is greater than that between the rows. This gives a slightly higher stand than square planting and allows more room for growing intercrops. As a guide, the number of plants/ hectare of the common planting systems is shown in table 1.

2.3 Holing and Planting

After laying out the marking pegs in the site, the next operation is digging of holes. The size of the seedling hole depends upon several factors such as the nature of the land, the type of soil, depth of water table, etc. Generally, the harder or heavier the soil, the larger should be the hole. For light soils, 0.5 m x 0.5 m x 0.5 m are recommended. For hard reddish clayey soil, 0.75 cu. m. is necessary so that the hardened portion of this soil would be broken. In sandy soil, shallow holes of one third to one half meter in depth are suggested. Surface planting is not advisable in places where drought prevails. It restricts the formation of the bole region and favors the formation of a shallow root system.

The holes are usually dug in advance of field-planting of coconut seedlings to allow the soil to weather. The surface soil is separated and the subsoil is utilized in making small bund all around to prevent rain water from flowing into the pit (planting hole).

The season of transplanting seedlings will vary from place to place depending upon the situation of the land and climat conditions. Generally, in most areas, the best time for transplanting is at the beginning of the rainy season or after its heaviest monsoon. Properly selected seedlings of either local

Table 1. Square and Triangular systems and their planting densities

M E T H O D		POPULATION DENSITY (Palms/Unit area) 1 ha	2 ha	3 ha	4 ha	5 ha
Square:	8 m x 8 m	156	312	468	625	781
	8.5 m x 8.5 m	139	277	415	553	692
	9 m x 9 m	134	247	370	494	617
	10 m x 10 m	100	200	300	400	500
Triangular:						
	8 m x 8 m	180	361	542	727	903
	8.5 m x 8.5 m	160	319	479	639	799
	9 m x 9 m	143	284	427	570	712
	10 m x 10 m	115	230	346	462	577

talls or hybrids raised under ordinary nursery or in black polybag nursery are ready for field-planting when seedlings reached 7-9 months of nursery period.

2.4 Care of Young Palms

The most critical time for the palm is during the early stages of its life, that is, from the time of planting to the third year. It is only by giving careful attention during this period that the palms could be expected to develop normally and produce high yields. This aspect can be demonstrated where newly planted seedlings are grazed by cattle, choked up by weeds and attacked by coconut pests and/or diseases.

.4.1 Fencing (presence of livestock) - The newly planted seedlings should be protected from the disturbance of cattle, until they grow big enough to be beyond their reach. An indirect damage done by cattle is trampling which hardens and exposes the ground around the young palms. If the seedlings are concentrated in one place, it is cheaper to fence the entire block or if this is not economically feasible, protection must be given to the individual seedlings.

2.4.2 Watering - In the absence of rain, the newly transplantec seedlings should be watered as needed until they produce enough roots and get established. It is also necessary to continue watering the seedlings during the dry months for the first two or three years after transplanting.

2.4.3 Shading - In some regions, when the sun is very hot during summer months, the seedlings should be adequatel provided with shade for the first 2 years. Shading reduces casualties among the newly transplanted seedling the frequency of watering, and checks the "grey blight" disease of coconut seedlings.

2.4.4 Cultivation and after care - The seedlings have to be kept free of weeds periodically. During heavy rains, precautions should be taken not to allow the water to stagnate in the hole for long periods.

[illegible] seedlings should be cleaned and the surface soil kept friable for faster root development. One sure way of keeping down weeds is to establish a leguminous covercrop which can smoother the weeds and at the same time increase the fertility of the soil. When covercrops are established, ring-weeding around the young palms should be widened. This will prevent the climbing up of the covercrop to the palms.

2.4.5 Fertilization - Proper fertilization from the nursery and/or field planting is necessary to give good start of the seedlings, unless the soil is virgin and with good inherent fertility. As experienced in many countries, proper fertilization of seedlings promotes early bearing and high yields. The major nutrient needs of the seedlings are potassium, nitrogen and chloride. Based on several studies conducted in different agro-climatic conditions in the country, an average fertilizer recommendation for coastal and inland coconut area was developed. This is shown in table 2 as a guide.

2.4.6 Protection from pests and diseases - The young coconut palms are susceptible to attack from various pests and diseases. Frequent inspection and monitoring of every plant should therefore be done and control measures taken promptly. Rhinoceros beetle, spike moth and caterpillar are some of the important pests of coconuts.

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Table 2. Average fertilizer recommendations (rate/palm) from field-planting to bearing stage for coastal and inland areas (more than 2 km from the coastline) (Magat et al., 1981).

AGE OF PALM	COASTAL AREAS			INLAND AREAS		
	AMMONIUM SULFATE (21-0-0)	+	POTASSIUM CHLORIDE (0-0-60)	AMMONIUM SULFATE (21-0-0)	+	POTASSIUM CHLORIDE (0-0-60)
Field Planting (FP)	150 g	+	100 g	150 g	+	200 g
6 months after FP	200 g	+	150 g	200 g	+	250 g
1 year	500 g/yr	+	500 g/yr	500g/yr	+	500 g/yr
2 years	750 g/yr	+	750 g/yr	750g/yr	+	900 g/yr
3 years	1.0 kg/yr	+	1.0 kg/yr	1.0kg/yr	+	1.6 kg/yr
4 years	1.50kg/yr	+	1.25kg/yr	1.5kg/yr	+	1.7 kg/yr
5 years or older	2.00kg/yr	+	1.50kg/yr	2.0kg/yr	+	2.0 kg/yr

- pre-bearing stage (1-4 years): split application, first half at start of rainy season and the rest six months after or before end of rainy season. Broadcast and fork-in (Soil-incorporation within 10-15 cm top soil) application

- bearing stage: One application for areas with even rainfall distribution (1.5 - 3.0 dry months); slpit application for areas with distinct wet and dry season. Broadcast and fork-in (soil incorporation) application.

Leaf spot, shoot rot and bud rot diseases are also observed to infect the young plants. Prompt measures taken in the initial stages alone will help to save the seedlings, hence, early detection is very important.

2.4.7 Replacement of missing hills - Provided all precautionary measures are taken, there should be no casualties (except due to lightning) of the transplanted seedlings. If however they do occur, they should be immediately replaced with selected and vigorous seedlings preferably of same age. Seedlings showing continued unhealthy and stunted growth should also be replaced. For this purpose, some surplus seedlings should be kept in reserve.

3. FARM MAINTENANCE

Although coconut is essentially a cash crop in most coconut-producing countries, it is also a food crop as well. The main consideration in farm management should therefore be to maximize the net income from it and this can only be achieved by increasing production, reducing costs, creating additional sources of income (intercropping) and proper disposal of major and minor products.

With the availability of superior planting materials (i.e. selected talls, hybrids) low productivity of many coconut farms is likely due to improper soil management. Application of proper soil management practices will help maintain high production levels. These practices that deserve serious attention in relation to coconut farming are: tillage, mulching, erosion control, covercropping, fertilization, green manuring, organic matter improvement, and soil amendments.

3.1 Tillage - In coconut farms, intercultivation or cultivating the interspaces is the main tillage operation and consists of plowing, harrowing and digging. Tillage has several objectives as follows:

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(1) To make the soil receptive to the first rain after a rainless period and to make it retain moisture;

(2) To produce favorable soil structure for the development of roots, thereby increasing the available feeding area for the palm;

(3) To improve the aeration of the soil resulting in increased bacterial and chemical activity which in turn increases the available plant food in the soil;

(4) To kill weeds, thus conserving both plant-food and water for the palm;

(5) To incorporate organic matter into the soil.

Felizardo (1972) showed that plowing, fertilization and covercropping practiced singly or in combination with each other increased nut yield in 45-year old coconut trees.

A distinction should be kept in mind between working the soil properly and the mere control of unwanted vegetation. Experienced gained in many countries has shown that working the soil has a beneficial effect on yield provided it is neither too frequent. The nutrient absorbing part of the root system is in fact very near the surface. If the soil is disturbed too deeply many roots will be cut or wounded, and yields may decline abruptly. But a shallow cultivation going down no deeper than 20 cm has a useful pruning action by cutting roots and acting as a stimulus to the root system to explore the deeper layers of the soil.

The best time to work the soil is near the end of the dry season. The coming of rains a few weeks later will favor the rapid development of young roots.

3.2 <u>Fertilization</u> - There is no contradiction to the fact that coconut palms do respond to proper fertilization particularly in coconut soils where there is an observed deficiency of major plant nutrients. Even if the soil is initially fertile, continuous

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removal of plant nutrients from the soil in large amounts is likely to create nutrient deficiencies sometime later, unless proper fertilization is done to replenish the nutrients absorbed by the palm. To avoid such problem it is highly suggested to follow a proper fertilization program as in Table 2. There are several approaches or methods that can be used to determine the fertilizer needs of the coconut. These are: (a) Soil analysis; (b) crop deficiency symptoms; (c) leaf analysis and (d) field fertilizer experiment or trial. The conduct of a fertilizer experimemt is the most precise method, though expensive and time consuming. Moreover, results obtained may just be highly applicable to the area the experiment was conducted (site-specific).

Soil analysis - refers to the chemical and physical measurements of the soil, diagnosis and recommendation. It has been practiced with some degree of success but generally workers are not satisfied with the reliability or usefulness of this method.

Crop deficiency symptom(s) - are exhibited by the coconut when it is unable to absorb sufficient nutrients to satisfy crop's requirements (Tables 3a and 3b). Symptoms of a nutritional disorder are confined to the leaves, and may occur in any part of the palm. Soil and leaf analysis are used to confirm nutritional deficiencies.

Leaf analysis (foliar diagnosis) - relates the concentration (%) of nutrients found in the coconut leaves which relate to crop growth or yield. The fertilizer and nutrition survey studies in the Philippines have shown that leaf analysis is an effective tool in diagnosing the fertilizer needs of coconuts, especially, the local talls, using the critical levels (leaf no. 14): 1.80% N, 0.12% P,

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0.80% K, 0.30% Ca, 0.20% Mg, 0.50% Cl and 0.15% S (Magat, 1978) and Magat et al., 1981). For hybrids, those critical levels may be used as a guide. In foliar diagnosis, a composite leaf sample from palms (10-20) under similar conditions is collected. For a particular stage or age of coconuts, leaf sampling is done on the selected leaf rank (no.) of palms. The selection depends on the number of living fronds or functional leaves at the sampling time. As a guide, Magat and Prudente presented a system for selecting the proper leaf rank for sampling (Table 4). If a more precise nutritional diagnosis and fertilizer recommendation is desired, coconut farms must be sampled separately and analyzed for leaf nutrient concentrations. In this way, the qualitative nutritional needs could be determined, and the kind and rate of fertilizer(s) is formulated based on the experience and knowledge of the agronomist/soil technologist/plant nutritionist using the foliar diagnotic technique.

3.3 Intercropping - In coconut farms where palms are planted at 8 m or wider, the interspaces may be used to grow other crops as a source of additional income. In the early stages of the plantation when palms are still young and the ground unshaded, there is no harm in raising intercrops provided care is taken. Intercrops should be fertilized and should not be grown very close to the base of the palm. It is best to allow 1.5 - 2.0 meters around the base of the palm uncropped and kept free from weeds.

The crops commonly cultivated in young plantations are: pineapple, root crops, grain crops, leguminous crops, vegetable crops, fiber crops, fruit trees and beverage crops.

Studies carried out by coconut workers have shown that intercrops can be grown without affecting negatively the yield of coconuts. In fact, fertilizing and irrigating the intercrops substantially benefits the main crop coconut. The result however

Table 3a. Average major nutrient requirements of coconuts.

AGE/STAGE	MAJOR NUTRIENT (g/palm)			MAJOR NUTRIENT (kg/ha)#		
	N	K	Cl	N	K	Cl
Nursery	12	25	22	1.2	2.5	2.2
Field-planting (FP)	30	50	44	3.0	5.0	4.4
6 mo after FP	40	75	66	4.0	7.5	6.6
1 year	100	250	220	10.0	25.0	22.0
2 years	150	375	330	15.0	37.5	33.0
3 years	200	500	440	20.0	50.0	44.0
4 years	300	625	550	30.0	62.5	55.0
5 years or over	400	750	660	40.0	75.0	66.0

#computed at 100 palms/ha

Table 3b.– Annual nutrient removal of hybrid coconut (ouvrier and Ochs, 1978) (Port Bouet 121 or MAWA, 6.7 t copra/ha at 138 palms/ha)

COMPONENTS	DRY WT. (kg/ha)	NUTRIENT (Kg/ha)							
		N	K	Cl	P	S	Ca	Mg	Na
Spikelet	492	3	14	11	0.42	1	2	2	3
Stalk	349	1	7	6	0.14	0.06	0.29	1	2
Husk	7,843	19	116	92	1.0	1	5	4	12
Shell	3,849	5	0	4	0.12	0.46	1	0.35	2
Meat	6,375	80	47	12	13	6	1	8	2
T O T A L	18,908	108	193	125	15	9	9	15	20
Annual Nutrient application (1970-75		41	235	235	15	104	-	55	--

Table 4. Coconut leaf rank recommended for sampling based on plant stage (Magat and Prudente, 1976)

MEAN TOTAL LIVING LEAVES#	LEAF RANK TO BE SAMPLED
4 - 6 (nursery)	1
7 -12 (nursery or field)	3 or 4
13 -18 (field)	9
19 or more (usually bearing)	14

#determined by testing 5-10 palms, randomly selected in an area.

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could be adverse if crops which are heavy consumers of potassium are planted without adequate fertilization.

The practice of growing perennial trees is common in the Philippines, especially in Southern Luzon, Eastern and Western Visayas and Mindanao. Coffee, cocoa, mango, lanzones and other fruit crops are being inter planted with coconut.

Intercropping of perennials in plantation where coconut trees are closely planted (7 meters or less) is less desired as such cropping will result to intense competition and adversely affect the growth and yield of both coconut and intercrops. Furthermore, under this situation it is difficult to give proper attention to the different kinds of trees according to their special and individual requirements. If, however, it is the intention to diversify the sources of income, two ways are open. One is to plant the trees in alternate rows giving sufficiently wide spacing to reduce mutual interference of one over the other and the second is to allocate different sites or blocks of the available area among the different crops.

3.4 Covercropping - Covercropping, the agricultural practice of establishing leguminous plant like tropical kudzu (Pueraria) to cover the soil, is accepted in the Philippines and elsewhere to have multiple benefits. This practice is extensively being done a few months before field-planting of the coconut seedlings as well as in areas with bearing palms. Progressive farmers in the country consider this practice important in their cultural management. The growing of leguminous covercrops cannot however be recommended under all soil-climatic set-ups. Among the factors to consider very importantly in selecting covercrops to establish in a particular coconut area as follows: (1) adaptability to local climatic and soil conditions; (2) ease to establish; (3) dry matter yield production; and (4) adaptability to local management practices.

Several benefits could be derived from this practice of leguminous covercropping, these are as follows: (a) helps eradicate/control unwanted weeds like cogon (Imperata cylindrica) and aguingay (Roettboellia exaltata), thus lowers the farm maintenance cost; (b) builds up plant food, especially nitrogen in the soil for the coconut crop via the nitrogen-fixing microorganisms associated with the legume covercrops; (c) conserves soil fertility by minimizing soil erosion, especially on sloping and hilly areas; (d) improves air and water circulation in the soil, keeping the soil porous desirable for normal growth and development of the palms; (e) encourages early-fruiting because of minimal competition for nutrients; and (f) fuel saver as instead of using an oil-driven tractor to maintain the farm/plantation in good upkeep by periodic cutting of weeds, an animal-drawn covercrop roller could efficiently regulate the growth of the leguminous covercrop by occasional rolling (say every two months).

In the Philippines, particularly in Davao, three kinds of covercrops are being recommended and widely used as follows:

1. Kudzu (Pueraria phaseoloides) - A twining perennial, with hairy stems and leaves. Leaves are broad, trifoliate and irregularly 3-lobed. The plant is good pioneer legume, which is adapted to many soil types (sandy to clayey) and is commonly utilized as a covercrop under coconuts rather than as a pasture legume.

2. Centrosema (Centrosema pubescens) - A trailing and climbing perennial, weakly rooting at the nodes and with bright purple flowers. It is adaptable to a wide range of soil types and will grow on acid soils and moderately tolerant of water-logged conditions. Growth is slow during the seedling stage, but becomes aggressive once the plant gets established.

3. Calopogonium (Calopogonium mucunoides) - A quick-growing creeping plant, which thrives on a wide range of soils and forms a cover in six to eight months, if sown under suitable weather conditions. Seeds are small, somewhat flat and yellowish brown. It is a moisture-loving plant and dies back during drought but regenerates after the rains.

As an important reminder, if the soil moisture is not adequate, covercropping may not be advisable as covercrops tend to compete with the coconut for moisture. Likely, weed is not a problem in dry areas and vigorous growth of weeds is encountered in areas with abundant rainfall and sunshine year round. Generally, in well-drained area with adequate water or soil moisture such as in places with high and evenly-distributed rainfall, covercropping is practical and beneficial.

3.5 Harvesting - From the complete reproductive fertilization of a female flower, coconut buttons take about twelve months flower, coconut buttons take about twelve months to develop into a mature nut. As a normal bearing palm produces an inflorescence in every leaf axial at intervals of about a month, a matured branch would be ready for harvest every month. However, harvesting is not ordinarily done every month except in high yielding farms or plantations, it being a costly operation, particularly when copra price is low. The harvest interval (frequency) practiced may vary from 30 to 60 days.

A study on harvesting frequency conducted at the PHILORIN (now PCA-Davao Research Center) at Bago-Oshiro, Davao City found that the 30 days interval gave the highest production cost, the 90 days interval the lowest productivity and the 45 days cycle gave the highest economic returns. From the result of the study, harvesting coconuts at 45-50 days interval gave the highest profit and is highly recommended.

The effect of harvesting nuts before they are fully mature on the quantity and quality of copra has been known. Copra and oil content per nut are at maximum in the fully mature (twelve-month old) nuts. By harvesting immature nut, copra is lost to the extent of 8% in 11-month old nuts, 16% in 10-month old nuts and 33% in 9-month old nuts. The loss in terms of oil quantity is directly proportional to that of copra loss. When nuts in a coconut bunch turns greenish brown or yellowish brown, the bunch is ready for harvest.

If the harvested nuts are placed in heaps for 12-15 days under the open-sun (seasoning) prior to extraction of coconut meat and drying, a further increase in copra weight (about 8%) is generally observed. The seasoning of nuts is highly recommended for those that do not exhibit the 12-month ripeness (dark brown).

4. OTHER AGRONOMIC PRACTICES

4.1 Drainage - The coconut palm cannot tolerate water logging stagnation) for a long period and consequently becomes poor nd stunted in growth, producing only very low yields. Thus, n water-logged areas coconuts should never be grown. However, hen the area can be drained, coconut can be made to bear atisfactorily. Drainage channels should be dug to take away the surplus water. These drains should not be allowed to get clogged up with weeds, rubbish or soil.

4.2 Erosion Control - Soil erosion is a serious problem in farms situated on hilly areas, particularly the ones subjected to heavy rains and flash floods. The loss of the top soil exposes roots and eventually creates nutrient deficiencies, thus coconu look diseased and become unproductive. A number of methods hav been suggested to minimize erosion such as terracing, contour planting, covercropping, etc. to suit different situations.

4.3 Green Manuring - Green manuring is the practice of introducing leguminous crops, plowed down and incorporated with the soil at green stage of the crop. Some benefits from green manuring are:

a. maintains the humus content of the soil;
b. stimulates biological activity in the soil;
c. exerts a conserving influence on soil nutrients and brings them upwards from the subsoil and deposits them within the root zone;
d. increases the availability of the inorganic constituents of the soil.

To get the maximum benefit out of green manuring, time of cutting and incorporation are important. Crop grown *in situ* is best incorporated at flowering time. If it is allowed to reach maturity (woody) then its green manuring value diminishes. The green manure crops should be incorporated when there is sufficient moisture in the soil.

4.4 Soil Conditioners - Application of lime to coconuts is practiced in coconut growing countries. Lime is applied to correct soil acidity (to reach pH 6-6.5). With proper application, it exert a beneficial effect by counteracting the high soil acidity (low availability of several elements and high fixation of phosphorus).

4.5 <u>Livestock-Coconut Integrated Farming</u> - Roughly 3 million hectares of land in the country today are planted to coconuts. About 0.5 million hectares of this coconut lands are stocked with livestock. Considerable interest has been devoted to this popular mixed enterprises, especially in many provinces in Mindanao (Southern Philippines).

Several reasons were cited why livestock are grazed under coconuts: (1) to provide feeds for work animals; (2) to maintain the plantation clean and (3) to generate additional income to the coconut farmer.

Like any other business ventures, however, this mixed enterprise has its drawbacks or limitation. Among the most common are the lack of sufficient feeds for the cattle to last the year-round, the depressing effects of grazing on coconut yields (especially on heavy soils and under improper pasture management); and lack of adequate financing. The first two factors are often results of the farmers lack of basic knowledge on management practices favorable to the livestock, the pasture and the coconut. Ideally, the system should be considered as a farming system rather than as separate enterprise

One major problem that result in integrating cattle with coconut is <u>compaction</u>, especially in heavy textured (clayey) soils. The grazing of cows and carabao (water buffalo) compact the soil due to trampling. Compaction of the soil surface reduces soil aeration and drainage resulting to low yields. Cultivating or subsoiling once every three years can counteract this ill-effects. It has been shown by Felizardo and Galvez (1961) and Felizardo (1971) that the yield of control trees did not significantly increased. The work proved that periodic loosening or tilling of the surface soil is a good cultural practice on grazed coconut farms. They likewise claimed that proper stocking rate and avoidance of overgrazing will also reduce soil compaction.

Another factor which needs serious consideration is the competition between the coconuts and the pasture grasses for soil nutrients particularly nitrogen and potassium. Grasses need mostly nitrogen for greater herbage production. Coconut, on the other hand, requires potassium, chloride and nitrogen in high quantities (refer to tables 3a and 3b) in that order. Obviously, there is a need to apply these nutrients to the soil in order for the coconut to remain economically productive and for the pasture to produce greater herbage yield (Alferez, 1975).

While it is true that many coconut farmers are intercropping coconuts with annual, biennial and perennial crops, yet there are still many areas that can be utilized for this enterprise. Experiences in Southern Philippines (Mindanao) have shown that a hectare of pasture under coconut can easily carry three (3) animal units for grazing under proper management, which is comparable to improved open pasture (Alferez, 1975).

Apparently, like intercropping, the integration of cattle in coconut farms offers a tremendous potential in increasing the income of the coconut farmer.

R E F E R E N C E S

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THE AGRONOMY OF CACAO[1/]

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INTRODUCTION

Cacao or cocoa is a stimulant tropical crop which grows best within a temperature range of 21-30°C, at altitudes of no less than 615 meters; a mean annual precipitation greater than 1,250 mm; with drought period no longer than 3-4 months; requires a deep top soil (at least 1.5 meters) well-drained, well structured; high moisture retention; rich in organic matter; and soils that are neutral to moderately acid in reaction and containing relatively high amount of exchangeable calcium and magnesium.[2/]

Cacao provides the best of chocolate beverage and confectionaries.

The productivity of cacao trees depends largely on several factors. Among these factors are, suitability of the area to cacao planting in terms of soils and climate, influence of planting materials; the variety and/or cultivar and the type of propagation, the degree of care given and the level of inputs provided as regards nutrition, shade management and crop protection. Efficient cultural management, therefore, spells the success in cacao production

CULTURAL MANAGEMENTS

A. Developmental stage (6-8 months before planting the cacao seedlings)

This stage embraces the preparation of material requirements prior to the planting of cacao. This includes the selection of the planting site, preparation of the site selected, survey and staking, preparation of shade trees, their planting and maintenance. Shade is needed by cacao plants during their early growth stage, to protect them from

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[1/] Paper read during the XIV International Forum on Soil Taxonomy and Agrotechnology Transfer at PCARRD, Los Baños, Laguna, Philippines, February 3-20, 1986.

[2/] Fertilizer Guide for the Tropics and Sub-Tropics by Jan G. de Geus, Centre de "Etude de L'azote, Zurich, 2nd Ed. 1973.

direct exposure to sunlight, strong winds and other adverse elements. It also, provides a kind of micro-climate which hastens development of the plants.

1. Selection of Site

The area should be of good drainage to allow good aeration and availability of nutrients; it should be near roads for future transport of produce; far from the community housing area which can encourage pilferage and stealing of products; must be near the source of water if irrigation becomes necessary and, also, for nursery use; and of good terrain to ease farm operations.

2. Land cleaning, plowing and harrowing

A sketch of the area is prepared, to designate blocking pattern, road positioning, location of farm houses and equipment.

If the area is cogonal, plowing is done at a depth of about 30-50 cms. This is carried out only once. However, if the area is with weeds other than cogon, plowing can be dispensed with. After plowing, one harrowing follows; then by herbicide application to further kill the weeds. All stones are then removed from the area, and placed along the boundary of the area.

3. Preparation of stakes, lining, staking and blocking

Bamboos or any woody plant material my be used for staking. They are cut about 3 feet long and tapered at one end. The efficiency of stake preparation is about 1,200 pieces per man-day. A nylon twine or string may be used for lining.

A triangular or quincunx planting pattern may be resorted to, with a planting distance of 2.75 meters x 2.75 meters. Before going into lining and staking, first prepare the nylon twine to be used in lining. For baseline-twine, marks are made on the nylon twine at 2.34-meter interval, while for the staking-twine, marks are at 2.75-meter interval, and further marked about 1.37 meters on both ends.

A baseline is established by spreading the nylon twine across the area. The stakes are then placed on every 2.34-meter mark. These serve as guides in staking the perpendicular lines. After having the baseline, start staking. The staking-twine is then placed on top of the baseline, marked 2.75-meter on top of the first stake of the baseline. Then, when it is spread on both ends, stake on every 2.75-meter mark. On the second line, place the staking-twine on the 1.37-meter mark, on top of the baseline having the 2.75-meter mark. This is done alternately until the whole area is staked. This operation takes 3 man-days per hectare.

. Shade Tree Materials

Preparation and planting

There are several tree materials which may be used to provide shade to young cacao plants. Some of these are cassava, madre de cacao and ipil-ipil.

Cassava provides the earliest shading but of short duration for the newly planted cacao seedlings. Another of its drawbarks is its being proned to pilferage. Some people may go for its tubers and at any moment thereafter this shade materials topple down or gets blown down with strong wind.

Madre de cacao provides shade but at a non-uniform coverage. Another of its drawbacks is its scarcity.

Ipil-ipil, on the other hand, grows faster provides uniform shade and builds up the organic matter of the soil during abcission of its leaves

On the 2.75-meter marks are planted the ipil-ipil seedlings and just adjacent to each in the inner portion of the row are planted the cassava stem (cuttings about 1 foot long). The cassava will ensure early shading. The ipil-ipil may be planted by direct seeding or better still with the use of pulled seedlings of about 1.5 to 2 feet long (from base of roots to its top) and having about 6 inches of roots.

5. Weed control

Where cogon grows, chemical weeding is employed. In situation where other weeds are present, manual weeding is used.

Slashing is done in between hills while roller is run in between rows, where thereafter herbicide is spread.

6. Replanting of missing hills (shade tree)

Missing hills are replanted with the same shade trees preferably during the rainy season. Shade trees are also planted alongside of those previously planted but are stunted in growth.

7. Fertilization of Shade Trees

To hasten growth and come up with vigorous shade trees, application of fertilizers to the crop is also necessary. Phosphatic and potassic fertilizers are usually applied on the ipil-ipil plants, while complete fertilizers are for the cassava.

Nursery Operation - (4-5 months)

Two months after planting of the shade trees, the nursery for cacao is prepared.

The size of a nursery shade is dependen on the number of seedlings required to plant a given area.

Example:

Area to be planted	-	100 has!
Distance of planting by quincunx	-	2.75 m. x 2.75 m.
Plant hill population	-	1,500/hectare

Therefore:

1,500 x 100 = 150,000 seedlings needed to plant the 100 hectares.

Size of the Nursery

given: post distancing in a square - 2.5 meters (6.25 sq. m.) from post to post

This can accommodate 300 seedlings; hence, 100 hectares will need a 500-squares or a total area of 3,125 square meter nursery. But, 10% additional seedlings are required as an allowance, to take care for replanting. Hence; the total area of the nursery will be 3,125 + (0.1 x 3,125) = 3,437.5 sq. meters.

The nursery area is land prepared by 3 times plowing, followed by 3 times harrowing. Post locations are then staked. Along each row, posts are installed at 2.5 meters apart. These rows are aligned on an east-west direction. The depth of hole for each post is 1.5 feet. The primary lintels are tied along the top side of the post on about 7.5 feet from the ground level. On top of these perpendiculars, the secondary lintels secured with nylon twine are spaced 1 foot apart, (at least 5 lintels per 1 square). Thereafter, a layer of coconut fronds is laid on top, to serve as roofing but spaced enough to allow minimal entry of sunlight. A 3-foot walling of coconut fronds in vertical position along edge of the nursery shed is provided to protect the seedlings from strong winds or astray animals.

Staking of bagged soil grouping

Each group of 7 lines of bagged soil are staked. This grouping is spaced 20 inches apart, and an alley of 1 meter around the nursery area is provided. Posts should be in between plots, to prevent obstacles during operation.

Bagging of Soil

Plastic bags, preferably black, 8 inches x 12 inches x 0.002 of an inch thick are filled with surface soil from inside the nursery shed. These are then arranged abreast with each other in 7 lines per group. Bagging efficiency is 400 bags per man-day

Preparation of seeds for Planting

Seeds are selected for good and productive cacao plants. Seeds should come from pods that are from the trunk of a stem, of a good stand cacao, free from diseases, of good shape and weight and from very productive cacao plant.

After selection, pods are broken with the use of a wood in a pod breaking table. Beans are placed inside a net bag mixed with sawdust, to remove mucilage and washed with water until the mucilage has been completely removed. These beans are then laid on jute sacks and finally covered with another jute sack. The set-up is then watered. This is to pre-germinate the beans which in the following morning, will then exhibit protrusion of the radicle.

These pre-germinated beans are seeded to each bagged soil. At least ½ of the bean with its radicle at the bottom is sunk into the soil. The un-germinated beans, after 5 days are then discarded. The efficiency of seeding is 10,000 beans per man-day.

Care of the Nursery seedlings

After seeding, these are sprinkled with enough water. Watering is done daily, if there is no rain. In about 2 weeks, the seeds shall have produced at least a pair of leaves.

Bags with dead leaves are separated for re-seeding and placed near the alley.

When the seedlings are about 1 month old, 0.5 g urea or a pinch is applied per bag; the rate is increased monthly by 0.5 g. If micronutrient deficiency symptoms show on leaves, apply the deficient micronutrient once in every 2 weeks by spray and at proper concentration. Azodrin 202 R or any other insecticide may be sprayed when insect damage have been observed. The earliest expected date of infestation is when the first leaf appears. A combination of Fungicide (Cupravit, Decis and Tenak) may be applied to control fungal and insecticidal damages on the seedlings.

Foliar fertilizer like Albatroz at 200 gms in 40 liters solution may be sprayed on the seedlings, starting when the first leaf matures and bi-weekly whenever necessary. A 0.5% ureal solution may be sprayed on the seedlings when they reach the age of 2 months and the plants would exhibit paleness.

Volunteer weeds may be checked by hand pulled as they occur.

As a sanitary measure, weeds along the alleys may be controlled, either manually or by chemical means.

Caution is given, in that, excessive watering of the seedlings should be avoided to prevent foot rot.

Care of the nursery will be continued until the 3rd up to 4th month when the seedlings are then ready for transplanting.

B. Pre-Productive Stage (6 months)

Planting of Cacao

Make a hole in between two ipil-ipil seedlings. In determining the size of the hole, use the spade as a guide. Four rounds of the spade make one hole, its size and depth. Be sure to separate the top soil from the sub-soil during digging. Hole digging efficiency is 300 holes per man-day.

Seedlings to be hauled are placed in a tray pan (to minimize stress on the plants and distributed to the field from a nursery, after digging the holes. 300 g calcic lime and 50 g solophos are applied to each holes, before planting.

During planting, be sure that the plant should be of the same level with the hole made and in covering with soil, it should be the top soil first, followed by the sub-soil. This somehow prevents the growth of weeds and most likely, more beneficial organisms are found in the top soil.

Planting efficiency is 300 plants per man-day.

Weed Control

Weeds are plants growing where they are not desired or plants growing out of place. They can be shrubs, broad leaves, grasses, sedges, bushes, aquatic or parasitic flowering plants. They compete for survival with cacao by way of grabbing the nutrients and moisture which should otherwise be utilized only by the cacao plants. They could also harbor insects and diseases which may attack the cacao plants. They, can also crowd the cacao plant. The foregoin undesirable characteristics of weeds, therefore, warrants their removal or eradication from the plantation.

There are two known methods of weed control and thes are, manual and chemical weed controls. In the manual method, with the use of grasshooks or scythe or slashing bolo the weeds are cut and eradicated. It may be line weeding or ring weeding.

In chemical weeding, two types of herbicides are used. These are the contact herbicide wherein the weeds are killed by mere contact with the chemical and the systemic wherein the chemical gets inside the plant and kills the plant slowly.

In cogonal areas, the weed control methods resorted to are a combination of the two. Maintain a 1 meter clean up ring weeding around the cacao plant and spray herbicides in between plants or a line slashing across the line of cacao plants and rolled with "pagulong" in between rows of cacao plants before spraying herbicides. On sparse cogon, "Haplas" method is employed whereby a herbicide solution preparation in a pail and with the use of a piece of cloth, leaves of cogon are wet one by one. This saves a lot of chemicals.

If the area are of different kinds of weeds, apply the manual method. This could be line slashing and ring weeding of 1 meter wide and same radius, respectively.

Chemicals used and Dosage

1. Spray method:

   Paraquat - 750 cc per drum (of 200 liters capacity plus Tenak 130 cc

   Dowpont - 3 kgs per drum plus 0.75 kgs Ammosul plus Tenak 130 cc

   Round-up - 750 cc per drum plus 0.75 kgs Ammosul or Urea plus Tenak, 130 cc

   Note: Stickers are used only during rainy season.

2. "Haplas" method:

   Dowpont - 100 grams per liter of water

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Efficiency: Slashing, ring weeding - 0.50 ha.

Chemical spraying - 1st 6 mos. - 1 ha.

- 1st year - 1-2 has.

Cycle: Monthly

Fertilization

Providing plant nutrients in sufficient amount and available to the growing plants is a very important requirement. Soil and leaf analyses more or less give one an idea of the soil fertility status and nutrient uptake of plants. With the use of critical nutrient levels both in soil and in leaves, the amount of nutrients by way of fertilizer application is determined. Others use the age of the plant and/or with crop yield as basis for determining the nutrient requirement of the plant.

Following is a fertilization scheme in one of the cacao plantation in Davao during pre-productive stage:

1. Pre-mix fertilizer with the following combination:

   grams/hill per application

Urea	-	9 grams
Solophos	-	10 grams
Potash	-	8 grams
Dolomitic lime	-	6 grams

2. Frequency of application

N and K	-	every 2 months
P	-	every 6 months
B	-	every 3 months
Mn and Zn	-	foliar once a year as needed

Dosage changes every 2 months of application.

Efficiency: combine fertilization - 4 has.

Cycle: 6 x year (every other months)

Propagation

As soon as the plant crop has been established, which takes 2-3 months after transplanting, asexual propagation is practiced. It may either be by budding or grafting. The idea is to have the desired variety.

Budding

Budsticks are collected from healthy, high yielding, disease - free, mature trees. The scion may be derived from a chupon or from a fan branch. It should be of chalk size, similar to the root stock and more or less brownish. The budstick is more or less, 1 foot long, with leaves removed, leaving about ¼ inch of the leaf petiole. A budstick of 5 should be wrapped with cacao leaves to prevent bruising and drying. Budding starts 2 to 3 months after planting.

Procedure in Patch Budding

The patch budding consists of removing a square or rectangular piece of bark from the stock and inserting in its place a bud of desired variety on a similarly shaped piece of bark. Two parallel cuts, 3/4 to 7/8 inch apart are made on the stock. The cuts should be made perpendicular to the stock and should be about 1 inch long. With a sharp budding knife, 2 longitudinal cuts are. They are likewise 3/4 to 7/8 inch apart, and each should intersect the two horizontal cuts, resulting in a square or rectangular patch. Similar cuts are made above, below and on each side of a bud on a budstick with the same tool that is used on the stock. Care should be exercised in removing the bud from the budstick in order to avoid splitting the bark beneath the bud. The bark should be lifted carefully on one side or both sides, if necessary, and the bud loosened by a lateral twist. The bud is held in place on the scion while the patch of the stock is flipped off and the bud is then quickly transferred to its place.

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In making the transfer it is important that the delicate cambium cells on the underside of the bud and on the exposed surface of the stock be subjected as little as possible to mechanical injury and exposure to air. The bud should fit snugly in its new location and should be tied immediately. It is then tied with plastic strip covering the whole patch. This is to secure the scion with the root stock and prevent entry of water.

21 to 28 days later, the plastic strip is removed. If the bud shows a sign of growth, make a girdle about 4 inches and ½ inch of the diameter of the stem above the bud. After 1 week if there's a protrusion of the bud eye, start bending. Bending is cutting almost half the diameter of the stem in a slide position resulting into a split of the stem but separation should be avoided.

Maintain the root-leaf ratio to keep the root functional in absorbing food or nutrients from the soil. After the 3rd flushing, cut the bended portion, about 1 inch above the bud and paint with coal tar.

Efficiency: 300 hills per man-day

Grafting

rafting is another means of asexual propagation. In here a fan branch or chupon are used as scion.

The scion is collected from a desired variety. The scion and the stock should be of the same size and age.

Make a diagonal cut on the scion, previously collected, about ½ of an inch similar to a chisel shape. The tapered portion should be smooth so as to fit the stock well. After the preparation of the scion, make a vertical cut on the stock of the same size. Insert the scion to the stock on a straight vertical position up to the last edge of scion's cut. Cover with plastic strip from below upward, covering the union of scion and stock and the whole part of the scion. This is to keep the scion and the stock in contact and prevent drying and the entry of water into the propagate. rtion.

When the shoot starts to come out, remove the plastic cover up to the joint point of the stock and scion.

Efficiency: 100 hills per man-day.

Pruning

Water sprouts are removed by pruning. This is to prevent growth of unnecessary chupons which if allowed to grow, will destroy the form of the tree and induce crowding of branches as to reduce the yield of the tree.

Should some of the fan branches develops towards the jorquette, these are removed and only 4 fan branches are allowed to grow.

Efficiency per man-day: 1 ha.

Cycle : every 15 days

Pest and Disease Control

The following are the insects that attack the plant at the pre-productive stage:

a. Mealybug - Sumithion, 20 cc per 10 liters of water plus foliar fertilizer

b. Nocturnal beetle - Sumithion, 20 cc per 10 liters of water

c. Cut worm - Kaffil, 5 cc per 10 liters of water

d. Lady bug - Sumithion, 20 cc per 10 liters of water

e. Ants (red or black) - Sumithion, 20 cc per 10 liters of water

Common diseases found in pre-productive stage

1. Vascular streak dieback
2. Pink disease
3. Stem canker

The above diseases may be controlled by way of pruning the affected portion/s of the tree.

Re-budding

Failures in budding are corrected by re-budding.

Replanting of seedling cacao

The need for replanting the missing hills is indicated by the number of stakes in each row which the sprayman has observed during his spraying operation.

Propping

In order to prevent abnormal growth of the developing chupon from the patch bud, a pole of ipil-ipil is tied abreast to it until its development has been completed.

Security fence

To secure the established plantings from stray animals and thieves, the area is fenced with barbed wires attached to the growing ipil-ipil. Established a 3-4 lines of ipil-ipil, adjacent to each other and along periphery of the area, accomplished by making furrows and seeding those to ipil-ipil. Growth of the ipil-ipil trees is regulated by cutting the trees to an appropriate height in sequence until the desired size of the stem is reached. The barbed wire is then attached to the outermost line of the ipil-ipil trees, at most of 7 strands.

C. Productive Stage (12 months)

Weed Control

At this stage, it is almost in close canopy a yet in some areas there will still be weeds which ma compete with the plant crop. Control measures are s to the field. It could be by chemical or manual mea

When cogon appears, use systemic herbicides, such as round-up or Dowpont. These are then sprayed on the grasses with the use of pak-a-bak 15-liter capacity. When cogon is sparse, "Haplas" method is necessary. This is to save cost on the chemicals. On other weeds, apply contact herbicides, such as gramoxone or paraquat. It is also of common practice to do slashing or under brushing on these weedy areas.

Efficiency per man-day:	Chemical - 4 has.	
	Slashing - 1 ha.	
Cycle:	Chemical - every 3 months	
		(4 cycles per year
	Slashing - every 2 months	
		(6 cycles per year

Replanting of cacao seedlings

During the operation, the sprayman should monitor the number of missing hills in each line. When the sprayman is about to transfer to the other row, he will put stake/s infront of the row. The number of missing hills corresponds to the number of stakes in the row.

On the other hand, when the tractors, loaded with seedlings arrive they will simply drop the seedlings accordin to the number of stakes that are infront of the row.

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<u>Thinning and Maintenance of shade trees</u>

As the cacao grows older, the need for shade reduces. It is then necessary to reduce the shading canopy of the shade tree. This is done by pruning and thinning and later by girdling the shade tree to be eliminated.

When the cacao plant reaches the age of 6-12 months from budding, the plant needs 50-75% shade (depending on climatic condition). Hence; when it is 12-24 months old, 30-50% shade is needed, followed by the gradual elimination of the shade tree.

Cut the shade tree about 7-8 ft. high, alternate in a row and let it sprout for 60 days. The tree which have been left, will be the next to be cut and of the same procedure. This is done alternately until it reaches the 25th month. This is to prevent abrupt change within the cacao environment, due to reduction in shade.

After the 24th month, start girdling the shade trees to be eliminated, retaining a buffer for strong winds, insects and diseases around the block every 2 hectares.

<u>Fertilization</u>

The fertilization scheme will depend on soil and leaf analyses and on the recommendation, thereafter.

Below is an example of a fertilizer recommendation for FY 1984-1985 in one of the cacao plantations in Davao: per ha. per year:

N - 250 kg, P_2O_5 - 103 kg

K_2O - 515.3 kg

Pest and Diseases and their Control

Pest (insects)

1. Pod Borer (*Acrocercops cramerella*)

A larvae from a nocturnal moth of 5-7 mm. long and with a wing span of about 12 mm. The adult moth lays about 40 eggs (ave.) on the surface of the cacao pods during night time. It lays eggs on exposed area of the pods. The eggs hatched about 3-7 days after laying. The larvae bore inside the pods feeding on the placenta of the beans cutting its food supply and stop bean from developing. The larvae stays inside the pods for about 17-21 days and goes out to pupate outside of the pod, leaves or even on litter in the ground. Pupal stage last for 7 days. The adult moth dies after laying eggs. After 7 days the pupae becomes adult and again repeat the cycle. Along the life cycle of the pest, the destructive stage is the larvae stage, the state where the control measure to break the cycle is necessary

Control Measures

1. Preventive - control measure be implemented in order to prevent the adult moth from laying eggs on the pods.

   a. Bagging - covering the cacao pods with plastic bags. This prevents the adult moth from laying eggs on the pods.

   Efficiency: 1,000-1,500 pods per man-day

2. Control

   a. Rampassen - a term given by way of removal of all pods for a month and at a time of low cropping season.

Disadvantages: It's hard to ensure that all pods will be harvested and besides, in the plantation, Malaysian variety has a continous cycle. Also other farmers grow cacao outside ghe plantation.

b. Chemicals - with the use of a systemic insecticide, like Decis, it stops the cycle of this pest. Spraying is done only on pods of baggable size while excluding pods which are already ripe.

Chemicals and their dosages

Decis	-	5 cc per 10 liters of wate
Sticker	-	2.5 cc per 10 liters of water

Sprayman's efficiency: 1-1.5 ha. per man-day

Pod Borer Survey

To minimize cost and determine the effect of the chemical used, a survey is formulated before spraying, if recommended and re-survey, if not recommended. This survey tells the percentage of borer infestation and is also a deciding factor whether spraying is needed or not. 1% or more spraying is recommended. If an area is recommended for spraying, the following week it is re-monitored. For those which are not recommended survey is done and remonitored to know the percentage infestation.

Survey proper

Sampling is done at random. A hectare is divided into 4 subdivisions or plots. Each subdivision must have 56 samples, so therefore, a total of 224 samples per hectare. In surveying, look for the entrance and exit holes of the borer on pods of eye level. Sample alternately on the first line with 9 hills, and when the 9th hill is reached turn on opposite diagonal direction counting 9 hills and again sampling alternately. Every time you reach the 9th hill, turn on opposite diagonal direction until you have 56-samples/plot (¼ ha). Aside from the exit and entrance holes, record how many pods were infested with black pods, how many were damaged by rat, and bored immature pods. % infestation is obtained by dividing the number of bored pods surveyed by the total number of pods surveyed, multiplied by 100.

Survey efficiency: 2 has. per man-day

2. Rats eat ripe cacao pods. They eat the placenta which is sweet, finally destroying the whole pod.
   Control: baiting with Rodenticide
3. Lady bug - feeds oh leaves
   Control: spraying with insecticides

   Chemicals and dosages

   Methyl Fosferno - 10 cc per 10 li of water
   Sumithion - 20 cc per 10 li of water
   Hostathion - 1.5 cc per 10 li of water
4. Scarring beetle - feeds on leaves
   Control: spray insecticides

   Chemicals and dosages

   Azodrin 202 R - 10 cc per 10 li of water
   Kaffil - 2.5 cc per 10 li of water
   Decis - 2.5 cc per 10 li of water
5. Tusock Moth - feeds on leaves
   Control: spray insecticides

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Chemicals and dosages

Azodrin 202 - 10 cc per 10 liters of water

Kaffil - 2.5 cc per 10 li of water

6. Mealybugs - feeds on flushes, fruits, and flower cushions. In symbiotic relationship with ants. Ants bring them up and feed on their secretion.

Control: spray insecticides

Chemical and dosage

Sumithion, 90 cc per 10 liters of water

7. Aphids and Plant hoppers - feed on leaves

Chemical Control: Sumithion, 20 cc per 10 li of water

8. Twig borers - feed on branches, thereby stopping the flow of food from stem to branches thus killing that part where the borer exists.

Control: insecticidal spray

Chemical and dosage

Azodrin 202 R, 10 cc per 10 liters of wate

9. Ambrosia beetle - from coffee, makes holes on stem, also, cutting the flow of food, thereby causing the attacked plant part to die.

Control: insecticidal spray

Chemical and dosage - Thiodan, 10 cc/10 li of water

10. Indian male moth - lays eggs on stocked beans, hatched and become larvae. The larva feeds on beans, creating tunnels on these beans. This lowers the quality of stocked beans.

Control: Chemical means by spraying or by drenching the sack with insecticide solution.

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Chemical and dosage

Decis spraying - 5 cc per 10 liters of water

Drenching - 10 cc per 10 li of water

Diseases

1. Vascular streak dieback - caused by Oncobasicium theobromae, a fungal organism.

Affected plants become less productive. Absorption of nutrients will also be affected, because the xylem and phloem vessels also get destroyed. The causal organisms is an obligate parasite that attack living tissues. The disease starts at the apical region, usually on flushes. Dissemination is only at night where they

Symptoms:

1. Yellowing of leaves, with green spotting
2. Leaf scar manifests 3 brown dots
3. General burning of mature leaves and flushes
4. Brown streaking on branches and on stem when split.
5. Stunting and no flushing

Control:

a. No reliable chemical control up to present.

b. By pruning the infected portion. Cut infected branches 6-12 inches from the last brown streaking and then paint with coal tar.

Control efficiency:

2 has. of young cacao trees or 1.5 has. of full growth cacao trees.

2. Thread blights - Marasmius spp. may appear as white mycelial thread or black fungal thread on leaves, petioles and branches. Penetrates branches on its xylem and phloem vessels which eventually get clogged causing death of affected branches.

Control: can be controlled by pruning all infected parts, 6 inches from the last infected area and finally burning these infected parts.

3. Pink disease - Corticium salmonicolor, a fungus disease that produces spores that are salmon pink in color on bark or branches of infected trees. At the time these spores are seen, the stage of development of the disease is way in advance. This pink color first was just a white powdery substance but later turns pinkish in color as the disease advances. On advanced cases, the portion affected will soon die and dry.

Control: Pruning - cutting the affected portion and painted with coal tar.

Chemical - scraping the affected portion and painted with coal tar mixed chemicals like Cupravit, Deconil or Benlate.

4. Black Pod Rot - Phytopthora palmivora, attacks stems and pods.

   Stem: bark seems to be roasted (black) from the base upward. This may cause death of the tree.

   Pods: black pods, pod rot - blackening and rotting of pods.

   Control: Cultural - removal of all infected parts which are then buried or burned. Avoid heavy shading and improved drainage.

   Chemical - spray with pristan

Pruning

Removal of diseased and undesirable branches and twigs; reducing the shade.

Disadvantages of no pruning:

a. Obstruct operations
b. Favors diseases, like thread blight and pink disease
c. Delays operations

Pruning at productive stage

1. Fan branch that grows inward the jorquet point
2. Branches that grow downward
3. Branches that grow 1-2 ft. from the jorquette point
4. Branches that grow straight upward
5. Branches beyond the reach of sprayman, during spraying
6. Water sprouts or chupon

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7. Diseased branch
8. Over branching or too much closeness of branches
9. Branches that overlap other tree

Efficiency: 0.25-1 ha./man-day

Cycle: 12 cycles per year or monthly cycle

Pod Count

Production forecast for the next 2 months is done by sampling, 7 samples per hectare usually in center line. It is the counting of all pods within the sample tree from a baggable size upward bay excluding ripened pods. While counting the pods, they are painted with color codes corresponding to the month, like red, white and blue. These color codes designate month are used alternately.

Recording: date sampled
color code
black no. and hectarage
Population x .9 (90% after deducting 10% from 100) x pods/tree (pod # + number sampled) = total estimate for harvestable pods in the next 2 months

Efficiency: 20-24 has. per man-day

Cycle: monthly or 12 cycles per year

Propping

During the first year of cacao production, weights of the fruits will become a problem. Records show that during its first year of production, high incidence of splitted cacao stem have been observed. This is due to the weight of pods that the tree could not support.

Because of this problem, the need of propping the cacao tree arises. With the use of a pole (ipil-ipil) tied on the tree, the tree is supported in carrying the weight of the pods. Also, tying the fan branches with a twine together, splitting of fan branches at the jorquette point is prevented.

D. Harvesting/Processing

Harvesting

With the use of harvesting knife, ripened (yellow or orange in color, depending on variety) pods are separated by cutting the stalk in between the pod and the flower cushion. It should be noted that in harvesting, the flower cushion should not be included, because once it is injured, the chance of bearing fruit becomes impossible. Damage pods are also included in harvesting like black pods, rat damage, bored immatured pods which are fully separated from good pods. Good pods are then sacked with harvester's code written in a cacao leaf and with 50 pods per sack. Sacked pods are then tied with parcela coded ribbon and placed along side of the parcela layout where it is hauled later.

Hauling

Harvesting/Production report serve as guide in hauling harvested pods. It tells where it originates (pla. # , blk. #) and how many pods had been harvested.

Hauling is based on priority, as to which will be hauled first: its distance, number of balance not hauled (if any), road status and amount of pods harvested.

The hauling team is composed of 3 and with an efficiency of 200 sacks per trip.

Harvested pods are then piled by parcela. Marked with parcela number, date hauled and number of bags.

Sampling

Sampling is conducted when the harvested pods have reached the fermentary house. About 5% of the total bags hauled are sampled. This reflects the harvesting procedure whether the harvest had been done properly; checks parcela harvester, regarding the quantity of pods sacked; monitors infested/damaged pods like black pods, rat damage, and counter checks monitoring of bored pods. Sampling is parcelarized.

Pod Breaking

Pod breaking is done by parcela. The number of bags in a certain parcela is divided into the number of pod breakers. These pod breakers get their share of the pods and place them beside their pod breaking table, ready for pod breaking.

A pod breaker has his own pod breaking table, 2 woven baskets (bucag), one for cacao good beans and the other one for the cacao shell. They also have sacks for pods infested with phytopthora (black pods) and bored pods. Defective beans are retained in the pod breaking table but later transfered to a sack for weighing.

Good beans are separated from infested beans. For counting purposes, if pods are infested with phytopthora (black pods), all of the cacao shells will be separated and put in a separate sack, while for severely bored pods the apical part of the shell is retained for counting and for slight bored and germinated pods, the half portions of cacao shell with stalk are retained.

Infested pods are categorized as slight and severe. Slight, when the damage is below 50% and severe, when it is 50% above. The beans are then classified as class A and B.

All beans without defects are class A and beans with defects, like germinated beans, bored beans and black pods, are class B.

All cacao shells, excluding the cacao infested with phytopthora, are crushed and distributed to the field.

The black pods are buried or dumped far away from the plantation, to prevent contaminating the other bearing cacao trees.

After breaking, all beans are then weighed, separating the weight of class A from class B. The defects are categorized as slight or severe and their amount recorded. Also, with the total weights of class A and B. All weighed beans are then ready for batching. Batching is referred to the group of pods broken during the period of 1 week, that is, all pods broken from Monday to Sunday are considered 1 batch.

Class A beans are placed in the fermentary box for fermentation while class B beans proceed to the wash box for further processing, to improve its quality. Beans that go to the fermentary box are then tagged with box number, date of pod breaking, batch number, classification and the total weight.

The first box is layered with fermented beans which serve as an inducer in the fermentation process. The fermented beans contain bacteria which cause the fermentation process. This bacteria are believed to be the initiator of fermentation.

<u>Fermentation</u>

<u>Procedure</u> (7 days fermentation)

1. Clean and remove all clogged linear air passages beneath the floor inside the first box, so as to allow air flow inside the box;
2. Layer [illegible] fermented beans to induce [illegible] fermentation

3. Pour the beans (recently broken) into the first box, and when about half of the box has been filled, layer again with fermented beans; this induces fermentation faster.
4. The beans will stay in the first box for 1 day only. This is without cover. The purpose of the first box is just to allow sweatings to flow from the box;
5. The following day (2nd and 3rd day) transfer the beans to the 2nd box. Before transferring, clean the linear air passages, removing the clogs before transferring the beans. In transferring, the time limit ranges from 30-40 minutes. This is done to maintain the temperature established before transferring or to lessen dropping of temperature. In this box there's a build up of temperature, about 34°C-44°C. In transferring, it should be noted that the beans should be mixed well and leveled. This prevents the beans from clustering or bonding together. After transferring all the beans, establish the holes, 1 for every sq. foot, (approx. 32 holes in one box) within the bulk of the beans. These allow the air to pass through the bulk of beans inside the box. Air is needed in the middle portion of the bulk to keep the bacteria alive and which are needed in fermentation. Cover the box with sack on the top portion to keep it moist and to prevent drying.
6. On the 4th day (4th-5th day) transfer the beans to the 3rd box, the same procedure as on the 2nd box. These beans will stay for 2 days in this box. The temperature ranges from 48°C-49°C.

7. Transfer the beans on the 6th day to the 4th box. (6th-7th day). Same procedure is to be done as in the 3rd box. On the 7th day, conduct a cut test on the beans, to see if the beans are fully fermented or not. If not, keep the box covered with sack, extending the stay of the beans in the box if necessary, but if already fully fermented, remove the sack cover. This is to reduce the continuous build-up of temperature due to bacterial action. Beans stay for 2 days.
8. On the 8th day, transfer the beans to the drier bed for drying.

Factors affecting fermentation

1. Duration (time factor) of pod breaking from harvest. That is, if it is stored before processing. If pod breaking is delayed for about 5-6 days, cacao pods become somewhat dehydrated.
2. Variety of cacao - different varieties have different levels of sugar content that affect the fermentation process.
3. Size of beans and quality of beans.

Changes that occur in the bean during fermentation

1. Breakdown of pulp with drainage of sweatings (fermentation pulp sugars to alcohol occurs with the rise in temperature).
2. Air access to the surface of the mass brought about by mixing the mass.
3. Bacterial oxidation of alcohol to acetic acid with further rise in temperature.
4. Death of germ due to temperature rise and which results in change of seed color.

5. Development of chocolate aroma and flavor.

Drying

Drying is important to prevent mold growth during subsequent storage.

There should be 2 drying beds in the drying section. The first bed is for skin drying while the second bed is for final drying.

First bed - from fermentary box, the beans are layered on the bed of same level and thickness. The beans are turned every hour by paddling equal distribution of heat and uniform drying. Mixing prevent clustering and bulking of beans. The temperature is maintained about 150-160°F. The beans stay here for 24 hours.

Second bed - the beans in here are almost dry. They are also layered in the bed of same level and thickness. Turning and mixing takes 3-4 hours interval. The temperature is lowered to 140°F-150°F. The beans stay for 24 hours drying. Conduct a moisture content test. Moisture content should be 5-7 before storing.

Sacking/Sorting/Grading

Dried beans are then sacked and weighed. Weight should be recorded and endorsed to the warehouse for recording purposes.

Unresorted beans are the classified accordingly, at the sortingarea. They are classified as Class A, B, C, and D.

Class A - 100-110 beans per 100 grams of beans

Class B - 1[illegible]0-150 beans per 100 grams of beans

Class C - washed beans or infested beans

Class D - Dust

D1 - Nibs

D2 - Flat beans and small beans

After sorting, sorted and classified beans are sacked in a jute sack ready for market. Sacks used are treated, drenched with systemic insecticide like Decis at 10 cc per 10 liters of water or sprayed at 5 cc per 10 liters of water.

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AGRONOMY OF SOYBEAN[1/]

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INTRODUCTION

Traditionally, soybean, which contains about 40-45% protein and 20% oil, is grown under upland conditions. With extensive land utilization, the growing of soybean is extended, i.e. intercropping with coconut and sugarcane and lowland rice-based cropping pattern.

Various advantages are obtained from growing soybeans. Being a leguminous crop, it is capable of fixing atmospheric nitrogen to reduce the plant's dependence on supplied N from fertilizers. The feed industry utilizes soybean as oil meal for poultry and livestock. It is a highly nutritious food mostly in the forms of soymilk, 'tahu' and 'tokwa' in the Philippines. It becomes a raw material for making of dyes, synthetic resins, lacquers, glues and paper coating.

The reported potential yield of soybean in some experiment stations in Los Baños, La Granja, Ilagan and Tupi is 5 MT/ha. However, the material average yield remains below 1 mt/ha. The field performance of soybean is influenced by three factors, namely, genotype, environment and management. Proper knowledge on the appropriate interactions of these three factors would be vital in increasing soybean yield under farm levels.

THE SOYBEAN PLANT

Soybean, similar to most crops, have two major growth stages, namely: the vegetagive and the flowering or reproductive stages.

The vegetative stages of the soybean plant covers about six to eight weeks. This period is between seedling emergence and the appearanc of the first flower.

[1/] Lecture for the XIV International Forum on Soil Taxonomy and Agrotechnology Transfer for the ASEAN Region held on March 3-20 1986 at PCARRD Headquarters, Los Baños, Laguna.

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Being a short-day plant, the span of vegetative stage and the onset of flowering depends on its photoperiod sensitivity. Most varieties start to flower when the daylength begins to shorten.

The amount of vegetative occurring after the beginning of flowering is also influenced by the growth habit of soybean. Growth habit of soybean may be determinate or indeterminate. The determinate types are those in which vegetative growth ceases once flowering has commenced both downwards and upward from this portion and both stems usually terminated with a cluster of pods. The indeterminate types, however, start flowering at the 4th or 5th node. Flowering progresses upwards. They continue growing vegetatively even after flowering has started and the main stem usually ends with a leaf.

The maturity range of soybean varieties in the Philippines is from 80 to 130 days. The reported time from germination to maturity in wet season is longer by 10 days among early varieties and 30 to 35 days among the late varieties than in the dry season!

Knowledge of the different stages of growth in soybean would be very useful in determining the proper cultural management needed to attain the potential yield of soybean under farmers' field conditions. Table 1 provides the general cultural management recommended for the growing soybean plant till its harvest time.

AGROCLIMATIC REQUIREMENTS

Soil Factors

Soybean is reported adaptable to a wide range of soil types. However, moderately fine, well drained and fertile soil (sandy loam to clay loam) with high calcium content is preferably. Soil pH 5.8-6.5 is suitable for both soybean and nitrogen-fixing bacteria. pH range of 6.0-6.5 is however, the optimum level for satisfactory biological activities of soil organism for nitrification, symbiotic nitrogen fixation and decomposition of organic

Table 1. Essential cultural mangement during the different stages of growth.

GROWTH STAGES	CHARACTERISTICS	CULTURAL MANAGEMENT
Germination and emergence	Seedling emergence from the soil	1. Good seedbed preparation 2. Depth of planting at 3-4 cm 3. Adequate weed control 4. Adequate moisture 5. Seed protection with fungicide
Unifoliate leaf	Nutrition of seedling	1. Fertilizer should be in band 3-6 cm to the side and slightly below the seed 2. No direct contact of fertilizer with the seed 3. Weed control
4-Trifoliate leaves to beginning of flowering	Branching occurs Photosynthesis active Nodulation active Subject to effect of daylength	1. Correct spacing and plant population 2. Control of insects 3. Weed control 4. Proper nutrition 5. Proper pH of soil 6. Pest control 7. Planting at the right season
Mid-bloom to full bloom	Flowering Flower abortion	1. Proper moisture 2. Correct plant population to get adequate pod height from the ground 3. Adequate nutrition 4. Weed control 5. Pest control
Beginning of pod development	Pod setting	1. Adequate nutrition 2. Proper spacing and planting rate
Rapid growth to green bean stage	Photosynthesis active Period of dry matter accumulation Growth of seed to maximum size	3. Weed control 4. Adequate moisture 5. Pests and diseases control to prevent defoliation
Approaching maturity to full maturity	Shedding of leaves Loss of moisture in the seed	1. Harvesting at 13% moisture in the seed

matter. When pH is below 6.0, apply 2/3 of lime requirement 3 months before planting and the remaining 1/3 just before the last harrowing (Table 3).

Table 2. A generalized liming table to adjust initial soil pH to pH 6.0 (From PR for Soil Fertility and Management, 1983)

INITIAL SOIL pH	AVERAGE AMOUNT OF LIMESTONE ($CaCO_3$)(t/ha) AT DIFFERENT SOIL TEXTURE				
	SANDY	SANDY LOAM	LOAM	SILT & CLAY LOAM	CLAY
4.0	2.0	3.5	4.5	6.0	7.5
4.5	1.5	2.5	3.2	4.2	5.2
6.0	1.0	1.5	2.0	2.5	3.0

Climatic Factors

Temperature, light intensity and rainfall distrubution directly affect the soybean performance under field conditions.

Soybean grows best in areas characterized by less rainfall during the wet season and only a short day session.

A temperature range of 22-30°C appears to be the optimum temperature requirement. At a fairly low temperature, emergence occurs late and very slowly, the seedlings are likely to suffer from the attack of microorganisms and the crop is a poor weed competitor. On the other hand, high temperature adversely affects growth, grain yield, oil yield and oil quality.

Light is an important factor in photosynthetic activities c a soybean plant. Low leaf area index (LAI) allows the light to penetrate the lower leaves contributing to the total dry matter production. High LAI reduces light penetration. Under shade conditions (40-50% light reduction), pod abortion (28%) and occurrence of diseases like powdery mildew and Cercospora are observed.

Soybean grows best in a humid climate with plenty of rain during the growing season and a dry weather during ripening. For optimum yield, the total requirement of soybean is 500-700 mm of water. Sufficient moisture is very important in these growth stages, namely: germination, flowering and pod-filling stages. In areas of the Philippines where a rainy season starts toward the end of May, planting time should not exceed mid-January to ensure that maturity and harvesting of the crop will not coincide with the start of rainy season in May.

PRODUCTION REQUIREMENTS

Selection of Varieties

The desirable characteristics of varieties to be selected for planting are high bean yield, early maturity, non-seasonality resistance to tolerance to pests and diseases and high adaptability to the prevailing soils and climatic conditions in the country.

Land Preparation

Good land preparation is important in good seed germination, seedling emergence, stand establishment stages and plant growth during the early growing period.

Under upland monoculture, the fields are usually plowed and harrowed two or more times when using a carabao-drawn plow and harrow. With a tractor pulled or mounted plow and harrow, one plowing is enough and two harrowings may be sufficient.

In rice-based cropping system under rainfed lowland conditions, conventional and zero tillage are commonly practiced. In conventional tillage, the usual number of the plowing and harrowings done in upland monoculture are adopted. In zero tillage, no land preparation is done prior to the growing of the next crop. The procedures followed include (1) drainage of paddy at least two or three days before the rice harvest (2) construction

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of shallow drainage canals along levees to improve surface drainage and prevent waterlogging and (3) opening a furrow and drilling of the seeds.

Higher net returns due to reduced labor cost from zero tillage than conventional tillage may be practiced. When soil moisture is not limiting, or irrigations can be provided, however, conventional method of land preparation can be used.

PLANTING

Time. Soybean is normally considered as an upland crop. In areas where irrigation is limited and soybean is grown under rainfed conditions, planting and cultivar selections may be based partly on rainfall patterns. In the tropics, soybean is grown in either or both conditions: wet season upland, dry season upland and paddy following rice. In rice-based cropping systems, soybean is grown in either patterns: rice-soybean, rice-rice-soybean or rice-soybean-soybean.

Soybean,a short-day plant, flowers only when daylength is shorter than its critical daylength in the Philippines, the dry season planting starts in October until the first week of November if enough moisture is available. During wet season, soybean is planted in the later part of May and in the whole of June.

Rate. The plant population and arrangement required to give complete ground cover depend on plant size which is a fraction of soybean cultivar and its growing conditions or seasons.

Short statured varieties usually produce their highest yields a closer spacings, than those required for tall growing cultivars.

In tropical countries, the planting rate recomemdnations for early maturing short growing varieties range from 300,000 to 600,000 plants/ha with row spacing of 30 to 50 cm. In contrast, planting rate for late maturing, taller varieties range from 200,000 to 400,000

Population density requirements depend on the growing season of soybean. In the Philippines, seeding rates for early and medium and la maturing varieties are higher during the dry season and lesser during wet season (Table 3)

Table 3. Recommended seeding rates and planting dates for the Philippine Seedboard Soybean varieties (From PR for Soybean, 1986, in press).

VARIETY	PLANTING MONTH	SEEDING Kg/ha	RATE SEED/HA	POPULATION PLTS/M ROW	DENSITY PLTS/HA
UPLB Sy - 2	May-June	56-60	22	18	300,000
	Oct. or late Feb.	75-80	22	24	400,000
BPI Sy-2	May-June	56-60	22	18	300,000
	Oct. or late Feb.	75-80	28	24	400,000

Seeds are planted 3 to 4 cm deep.

WATER MANAGEMENT

Soybean is responsive to irrigation especially at its reproductive phase. The recommended water depth is 40-60 cm per season. The first irrigation is done after planting. The other remaining are applied during the period of blooming to pod-setting.

FERTILIZATION

Soil analysis is recommended to be done prior to soybean plantin to determine the type and rate of fertilizer to use. In the absence of this procedure and during dry season cropping, the soybean planted afte corn or rice is fertilized with three bags ammonium phosphate and one muriate of potash (24 kg N, 30 kg P_2O_5 and 30 kg K_2O). If these fertil are not available, use of 4 bags of complete fertilizer (14-14-14) can be done. If seeds are properly inoculated with rhizobia, application of 30 kg P_2O_5/ha and 30 kg K_2O may be sufficient.

The fertilizers are applied evenly in the furrow and covered witl 2 or 3 cm of fine soil. The seeds are then drilled above the covered fertilizers. This practice makes the fertilizer readily available to the roots of the young seedling.

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INOCULATION

Soybean is estimated to fix 17-124 kg N/ha/year which is equivalent to 1.7 to 12.4 bags of ammonium sulfate. This wide range indicates differences in effectiveness or capacity of the symbiotic system to fix nitrogen. In order to assure in getting maximum benefit from the legume-rhizobia symbionic, inoculation of seeds must be done to put in the right rhizobia to the soybean seed.

Rhizobia can be introduced by seed inoculation or by soil inoculation. Under seed inoculation, three methods are used, namely: dusting, slurry inoculation and seed pelleting. In dusting, the inoculant is mixed with the seed. This method, however, is not recommended because most of the inoculant falls off from the seed. Slurry inoculation involves adding water to the inoculant to form a slurry and mixing it with the seeds or the seeds are moistened prior to the application of the inoculant. For effective coating, an adhesive gum as gum arabic or methyl cellulose is used instead of water. Seed pelleting has been used to overcome problems in soil acidity to protect rhizobia inoculated to dry seeds grown in dry soils and to protect inoculated seeds from coming in contact with superphosphate. Pelleting is done by coating of the seeds with the slurried peat inoculant containing adhesive and then coating the moist inoculated seed with finely ground $CaCO_3$ (300 mesh) or a special grade of rock phosphate or dolomite. The other method, soil inoculati allows the introduction of high numbers of rhizobia. It is also recommended when seeds are treated with pesticides which may be toxic to the rhizobia.

The legume inoculant is prepared by mixing a broth culture of Rhizobia with a suitable carrier and incubated for two weeks to have a population of approximately 10^9 cells/g. A mixture of soil, charcoa and wood ash is found a suitable carrier. It is also recommended that inoculants should contain 10^8 to 10^9 cells/g at the time of sale.

Two weeks afger planting, observations on positive indications of the success of inoculation are done. The failure of inoculation indicated by the yellowing of the soybean leaves can be caused by any of the following:

1. The inoculant may be ineffective, non-viable or unsuited for the variety.
2. The soil condition may be unfavorable.
3. The soil has a high population of effective and competitive Rhizobia for the legume under cultivation.
4. The host or the bacteria are limited by the lack of some nutrients.
5. Presence of soil microflora antagonistic to rhizobia.

WEED CONTROL

The ten most commonly found weeds of soybean in the Philippines are Rottboellia exaltata L.f., Ipomoea triloba L., Elcusine indica L., Echinocloa colona L., Amaranthus spp., Digitaria spp., Commelina benghalensis L. Boerhavia erecta L., Cynodon dactylon, Cyperus rotundus L. and Portulaca olaraceae.

The common methods of controlling weeds are:

1. preplant land preparation
2. handweeding
3. interrow cultivation
    a. off-barring done 14-18 days after sowing
    b. hilling up done 26-34 days after sowing
4. mulching with rice straw and other crop resi
5. chemical control

Combinations of some weedicide and cultivation yield results comparable with that of the handweeding (Table 4).

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Table 4. Soybean yield as affected by different wedd control methods[1/] (From Robles, 1985).

METHOD[2/]	TIME OF APPLICATION DAS[3/]	YIELD (t/ha)
Metibuzin (0.5) + handweeding	PE + 20	1.47[a]
Off-barring + handweeding + hilling up 4 x until 40 DAS	14 + 28	1.43[a]
Handweeded check	-	1.42[a]
Butralin (3.0) + handweeding	PE = 20	1.41[a]
Handweeding	20	1.24[b]
Metribuzin (0.5)	PE	0.96[bc]
Off-barring + hilling up	14 + 28	0.92[bc]
Unweeded		0.75[d]
Butralin (3.0)	PE	0.88[d]

[1/]In a column means followed ot a common letter are not significantly different at 5% level.

[2/]Herbicide rate in Kg ai/ha in parenthesis

[3/]DAS- days after sowing: PE = pre-emergence

DISEASE CONTROL

Common soybean diseases found in the Philippines include soybean rust (Phakopsora pachyrhizi Syn), bacterial pustule (Xanthomonas phaseoli) (E.F. Smith) var sojinsis (Hedges) Starr and Burk, soybean mosaic (rod like virus), damping-off and root and stem rot, blight, wilt (Sclerotium rolfsii, Rhizoctonia solani) (Cercospora kihuchii) (T. Matsu and Tomoryasu) and anthracnose.

The most practical and economical disease control measures are use of resistant varieties and sanitation.

INSECT CONTROL

Important insect pests of soybean are beanfly (Ophiomyia phaseoli) (Tyron), leaf miner (Stomopteryx subsecievella) (Zeller), common cutworms (Spodoptera litura) (Fabricius), ophia (Aphis craccivora Koch and Aphis glycines Matsumura), coffee leaf folder (Helicoverpa armigera Hubner), corn semi-looper (Chrysodeixis chalcites) (Esper), bean pod borer (Maruca testulalis (Geyes), bean lycaenid (Catochrysops cnejus Fabricius) and leafhoppers (Empoasca biguttula (Ishida).

The common way of controlling them is by use of chemicals recommended by the manufacturers. Example is Azodrin 202R (2 tbsp/20 l) for control of beanfly, leafminer, aphids, leaffolders, and common cutworm.

HARVESTING

Soybean is harvested when the leaves have fallen off and pods are fully dry (about 89 days after planting during the dry season). It may be harvested by cutting the stalk at the base and by mechanical harvesting in highly commercialized farms.

OTHERS

Soybean Pilot Production Program

This program was launched on December 1983 by PCARRD, UPLB, CLSU and MAF with financing by NSTA to boost the national soybean production. In general, its objectives are (1) to identify and assess additional potential areas for the commercial planting of soybean, (2) to promote the commercial planting of soybean in areas with comparative advantage over other traditional crops (3) to evaluate the applicability of current soybean production technologies under various agro-climatic environments.

The four major activities of the program involve (1) seed production/multiplication, (2) piloting of soybean production technologies for post-rice soybean monoculture and corn-soybean [illegible] cropping, [illegible] credit assistance.

PCT/Package of Technology

The program is basically a one-crop-one season activity using the recommended package of technology (POT) for soybeans. Under favorable conditions, this POT is estimated to produce 1.25-2.00 m.t. soybeans/ha. Generally, the POT uses introduced and/or developed high yielding soybean varieties and good quality seeds, is designed for dry season cropping in areas with complete or partial irrigation, uses inoculants either singly or in combination with inorganic fertilizers and works well under light-to-medium textured soil with a pH 5.8-6.5.

The average yield per hectare increased from 678.12 kg in 1983-84 to 825.03 kg in 1984-85 (Table 5). Although the yields were still way below its potential and are unstable, soybean production in the two pilot sites, continue to slowly grain headway in becoming an important component of the area's existing cropping systems. Planting soybean after rice at the end of the rainy season has been constantly drawing favorable response from many farmers' group.

Table 5. Average yield (kg/ha) of soybeans in two locations, 1983-84 and 1984-85 croppings.

PIOOT AREA	MEAN YIELD/HECTARE (Kg/Ha)	
	DRY SEASON 1983-1984	DRY SEASON 1984-1985
Nueva Ecija	1,173.80	832.85
Cagayan	191.60	790.18
AVERAGE	688.12	825.03

Generally, soybean yield in Nueva Ecija was consistently higher than those obtained in Cagayan due to the greater availability of irrigation water during the growing period of soybeans. However, the cost of production in Cagayan was cheaper by 42% (Table 6). The difference lies in lower labor cost and land rental and lesser application of chemicals, fertilizers and irrigation water in Cagayan. Consequently, Cagayan Farmers recieved [illegible] 85 dry season.

Table 6. The average costs and returns per hectare of soybeans in Nueva Ecija and Cagayan, DS 1984-85

I T E M	NUEVA ECIJA	CAGAYAN	AVERAGE
GROSS INCOME (US $)	433.08	426.70	429.02
- Average yield/(Kg/ha)	832.85	790.18	825.03
- Average buying price/ kg (US $)	0.52	0.54	0.52
COST OF PRODUCTION (US $)	306.78	177.73	278.24
- Variable Costs			
Labor	86.55	64.29	82.52
Seeds	28.28	23.00	27.30
Fertilizer	53.94	47.00	47.76
Chemicals	33.67	11.00	29.51
Irrigation	22.67	0	18.49
- Fixed Costs			
Land rental	71.56	23.39	62.73
Depreciation	6.57	8.97	7.13
Interest on loan	3.44	0	2.80
NET INCOME (US $)	126.30	248.97	150.78
RETURN ON INVESTMENT (%)	41	140	54
COST PER KILO (US $)	0.37	0.22	0.34
BREAKEVEN YIELD (KG/HA)	590	329	535

*Estimated current landed cost of raw U.S. soybeans = US $0.32/kg.

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THE AGRONOMIC AND CULTURAL PRACTICES OF THE OIL PALM (Elaeis guineensis) IN MALAYSIA[1/]

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HISTORY OF INTRODUCTION AND CULTIVATION OF OIL PALM IN MALAYSIA

Growing and planting of oil palms in South East Asia (Far East) started with the introduction of four seedlings from Reunion and Holland into Jawa in 1848. From these four seedlings planted at the Botanic garden in Bogor, the oil palm (Elaeis guineensis) spread through Jawa (Banja Mas) and Sumatra (Deli) to Malaysia in 1911-17. Commercial planting of oil palm commenced in the late 1930's (1938) with about 30,000 ha planted mainly in West Coast of Peninsular Malaysia Expansion of oil palm planting in Malaysia started after the Second World War and achieved tremendous momentum from 1960. The extent of cultivation of oil palm in Malaysia is shown in Table 1.

ORIGIN AND NATURAL HABITAT

The type of oil palm introduced and planted is the Elaeis guineensis which is native to Central West Africa; in Nigeria, Zaire, Cameroon, Equatorial Guinea, Guinea, Ghana, Ivory Coast and Angolia.

In Africa, the fresh water swamps and river floodplains have been suggested as the natural habitat for the oil palm which cannot tolerate permanent flooding or stagnant water but appears to be tolerant of fluctuating water table and moving water in riverine alluvials. However, it has also been noted that oil palm, probably due to man's doing also grows in forest fringes or in forest areas which have been cleared for cultivation.

The oil palm, mainly by the act of man, has now a wide distribution and can now be found in almost all the equatorial countries in the World. Within 7° of the equator and in some exceptional areas at higher altitudes, the typical African oil palm (Elaeis guineensis) has been cultivated fairly extensively.

[1/] Lecture for the XIV International Forum on Soil Taxonomy and Agro-technology Transfer, Philippines, March 3-20, 1986.

Table 1. Planted Area Under Oil Palm In Peninsula Malaysia (In Hectares)

YEAR	MATURE	IMMATURE	TOTAL PLANTED
1960	40,024	14,610	54,634
1961	43,302	13,841	57,143
1962	46,175	15,904	62,079
1963	49,073	21,957	71,030
1964	52,436	30,764	83,200
1965	58,544	38,403	96,947
1966	65,860	56,843	122,703
1967	74,992	78,618	153,610
1968	92,104	98,661	190,765
1969	115,386	115,790	231,176
1970	138,902	122,297	261,199
1971	169,482	124,667	294,149
1972	208,129	140,612	348,741
1973	250,338	161,732	412,070
1974	290,291	209,953	500,244
1975	340,971	227,799	568,770
1976	403,157	234,460	637,617
1977	490,676	221,326	712,002
1978	348,400	90,500	438,900
1979	382,700	80,700	463,400
1980	407,800	87,600	495,400
1981	440,400	110,600	551,000
1982	470,800	103,800	574,600

Note: (e) - Estimates

Source: 1. Dept. of Statistics
2. MOPGC

In Malaysia, the oil palm has been planted as commercial groves (smallholder) and on plantations from the coastal plans to the hills and sometimes mountain, on all kinds of soils and terrain, but the coastal plain with riverine and marine alluvials are the preferred situation and location.

BOTANICAL CHARACTERISTICS AND TYPES

The oil palm is a large feather-palm having a single columnar trunk (stem) with short internodes. It is quite like a coconut palm but can be distinguished from the coconut palm by the much larger number of leaves with pointing leaflets and persistent leaf bases which are closely adherent to the trunk (stem) during the first 10 to 15 years of its life. The palm is normally monoecious with male or female but sometimes hermaphrodite inflorescences borne on short stalks (compared to the coconut inflorescence), in the axils of the leaves. Each leaf normally subtends an inflorescence in its axil and there are about 50 leaves on the palm.

The stem (trunk) is usually straight and upright except in soils which provide poor anchorage, as in deep peat or organic clay/muck. The trunk, depending on the variety, normally grows about 40 to 60 cm in a year.

Leaves are borne and arranged in two sets of spirals or parastiches (phyllotaxis) to the stem; eight running in one way and thirteen in the other. Such arrangement (or phyllotaxis) is described as (8 + 13). This is well shown in the pruned trunk. The spiral can be left or right handed. Leaves are persistent and normally adhere to the trunk until after 10-12 years when the bases become rotten and decayed. Number of leaves produced increases between 30 to 40 at 5-6 years, thereafter decline to about 25 per annum.

The roots of the oil palm are fibrous and adventitious. Roots are of four sizes; the primary (5-10 mm), secondary (1-4 mm), tertiary (0.5-1.5 mm) and quarternary (0.2-0.5 mm). The primary roots are mainly anchorage and grow either vertically or horizontally. Secondaries arise from primaries, and the tertiaries from the secondaries. The tertiaries and quarternaries are feeding roots and ramify the soil surface in the upper topsoil. Density of roots in the top 40 cm of soil usually decreases with distance from the palm and root may extend to over 10 m. The greatest quantity of roots is in the top 15-30 cm and within a radius of 3.0 m.

Roots of all classes respond to environmental condition or cultural practices and grow towards water and nutrient supplies. Hence, density of roots (all classes) is greatest in fertilizer application zone, leave/frond heaps or under good leguminous covers (diagram or root distribution).

The inflorescence is a compound spike or spadix and the flowers, male or female, are borne on the spikelets or spadix. The inflorescence has a stout stalk or peduncle about 45 cm long and spikelets are also arranged spirally around the rachies. There are several thousands of female flowers and tens of thousand of male flowers in an inflorescence.

The fruit is a sessile drupe varying in shape from nearly spherical to ovoid or elongated. Fruits consist of outer exocarp (or skin) and mesocarp containing fibres, moisture, solid and fats, oil protein, gums, carotenoids etc. and endocarp (shell) of lignified material enclosing the kernel. According to the pigments in the exocarp during ripening, the fruit types are named nigrescens (black to orange red), virecens (green to light orange), albecens (ivory to pale yellow). There are also intergrades - rutilo, rubro nigrescens, albo-nigrescens and albo-virescens. According to the thickness of the shell, the fruits have been classed into 3 varieties.

Dura - thick shelled, 2-8 mm and no fibre ring.
Tenera - intermediate thick shelled, 0.5-4.0 mm, thick fibre ring
Pisifera - shell-less, fibre ring may be present.

Commercially, planted varieties were, until recently (after 1960), Duras or mixed Duras and Teneras. After 1960, mainly Teneras, which is a hybrid between Dura and Pisifera were planted.

Recently, interests on the other oil palm species have increase due to its slow growth in height. The American oil palm, Elaeis oleifera, which is native to Latin (Central) and South America; Mexico Honduras, Guatemala, Panama, Guiana, Costa Rica, Surinam, Brazil and Columbia is more tolerant to diseases and has higher content of unsaturated fatty acid. These palms have been called E. melanococca, Corozo oleifera or Alfonsia oleifera. They differ from E. guineensis in having coiling and recumbent slow growing trunks, thick set and larger leaves and smaller fruits, but much larger bunches/inflorescence with persistent sheaths or spathes. Their natural habitat is also similar to that of the E. guineensis: in damp and swampy situations or riverbanks (slide showing E. oleifera). Of interest is the inter-specific hybrid of this oleifera with guineensis which partakes the characters and morphologies of both parents (slide showing hybrids).

ENVIRONMENT: CLIMATE AND SOILS

The oil palm is grown in regions differing widely in the climatic and soil conditions; from drought stricken areas with marked, extended dry season of 2 to 4 months and annual rainfall of less than 1300 mm in Africa, to areas with well distributed rainfall exceeding 5000 mm and no dry season or drought (South East Asia and South America), and on sands to heavy coastal alluvial clays and on soils formed of basalt or fresh (relatively) volcanic material (pumice and ash in Papua New Guinea). However, areas with the highest productions have the following climatic features.

i. A rainfall of 2000 mm (80 ins) or more evenly distributed through the year with no very marked dry season.

ii. A mean maximum temperature of about 29°-33°C (85°-90°F) and a mean minimum temperature of about 22°-24°C (72°-75°F).

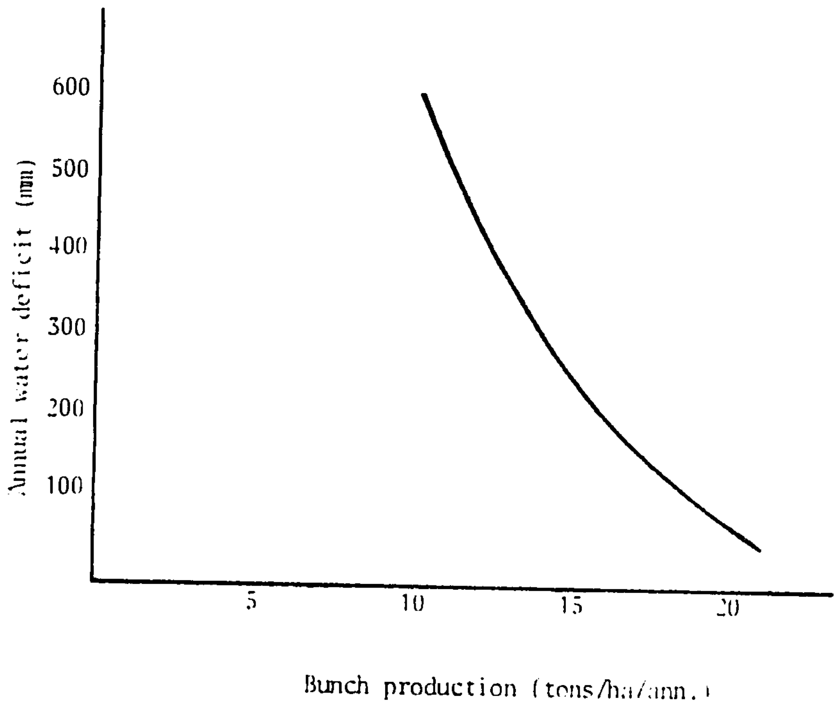
iii. Constant sunshine amounting to at least 5.0 hours per day in all months of the year, rising to 7.0 hours in some months.

Of these climatic factors or parameters, the most important is the distribution and amount of rainfall/precipitation and the annual water deficit, resulting from the interactions of these climatic factors and soil characteristics. The general relationship between water deficit and bunch yield in Africa (Ivory Coast) is shown in the following Figure 1.

Fig. 1. Relation between the annual water deficit and bunch production on Class 1 soils (I.R.H.O.)

More direct relationship of rainfall on yield and production of bunches has been investigated. Several models, incorporating the climatic parameters and the yield components, have been examined and proposed. More recently in Malaysia, partial correlation analysis has been used to determine relationship between oil palm bunch yields and changes in rainfall and dry spells. It has been found using this approach (Exploratory identification analysis), that bunch yields are associated with rainfall 16-18 months and 22-23 months previous, and dry spell at 29-30 months previous. Bunch yields is

Figure 1. Relation between the annual water deficit and bunch production on Class I soils (I.R.H.O.)



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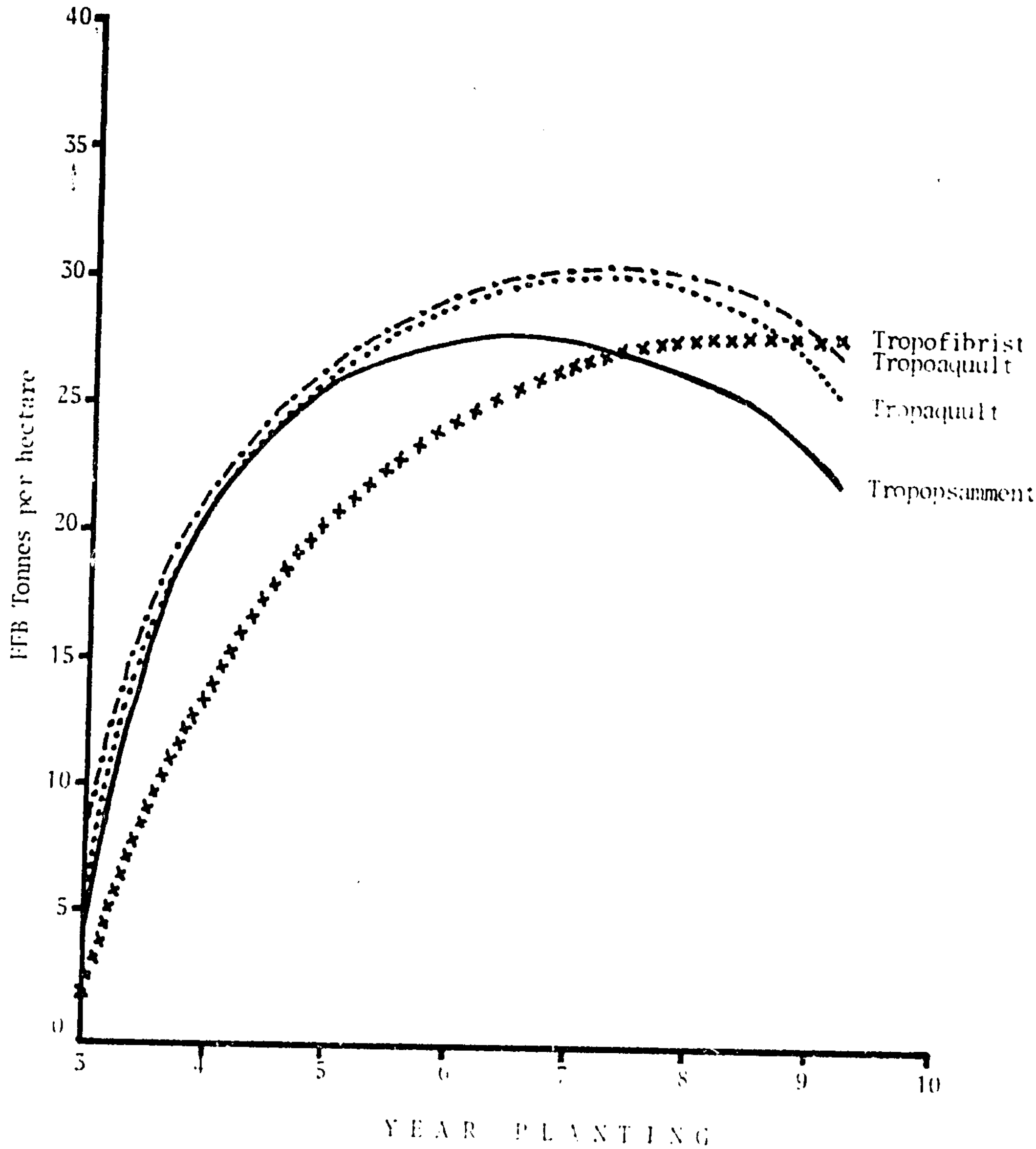
negatively correlated with rainfall 16-18 months previous but positively correlated with rainfall at 22-23 months previous and with dry spell 29-30 months previous. Although the correlation coefficients (about 0.50) of these relationships were calculated, the yields were not predicted and the study on the function has yet to be completed.

The oil palm has been cultivated and planted on a wide range of soils, ranging from loamy sand to heavy clays and fairly deep peat and on various slopes, from flat or even depressional land to hilly areas with slopes greater than 25°. In Malaysia, in order to reduce cost of establishment and to minimize the difficulties of harvesting, and erosion hazards, cultivation of oil palm is not recommended on slopes greater than 15°. It has also been observed that physical soil properties, like depth, texture and structure, are more important in deciding or determining the suitability of the soils for oil palm planting, as these affect the anchorage and penetration of the root (root growth/development) and the water and nutrient retention capacity of the soils.

In Malaysia, the recent marine and riverine clays, sub-recent alluvials and a wide range of sedentary soils derived from igneous and sedimentary rocks are found to be quite suitable for the cultivation of oil palm. On the other hand, soils with hardpan or plinthite (lateritic) near the surface, poor drainage and acid sulphate condition and organic soils and sands have been considered unsuitable and should be avoided. Experiments have been carried out by planting oil palm on these soils with these serious limitations, and growth and yields have not been satisfactory without any input to ameliorate and improve these limiting conditions.

The yields and growth of oil palm on three of these soils in Malaysia, have been compared and are shown in Fig. 2.



Yield trend of oil palm on different soil types

Source: Adapted from Ng and Thong (1985)

Over the last decade or so, attempts and efforts have been made to improve the cultivation or growing of oil palm in these less favourable soils; the organic soil (peat deeper than 1.0 m), acid sulphate soils and the lateritic soils. Methods and measures employed include the following:

On deep peat greater than 1.0 m - Pre drainage and intensify drainage followed by compaction and consolidation of the organic matter using compacting machines or heavy roller. After planting with oil palm, use and application of fertilizers including those containing trace elements, mainly copper and iron, are liberally applied. In some places, application of lime or limestone dust is also made to improve and enhance or accelerate decomposition and mineralization of the organic matter. Foliar applications of trace element solution were also found to be quite effective for correction of such deficiencies on younger palms.

On acid sulphate or potential acid sulphate (Para acid sulphate) soils, control of excessive drainage and maintenance of the water table above the oxidation zone, together with the application of alkaline fertilizers or liming have been found to be successful and effective amelioration methods for the oil palm growing on these soils.

On the lateritic soil and sands, mulching with empty bunches or other vegetative or plant materials have been tried. More recently, use of palm oil mill and rubber factory effluents have been tried and investigations on their uses on these soils are being continued with increasing interest. Results so far appear to be quite encouraging.

PLANTING OF OIL PALM AND HUSBANDRY PRACTICES

It is convenient to divide the cultivation and planting practices of oil palm into two aspects viz.

i. Nursery establishment

ii. Field planting

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1. Nursery Establishment

Nowadays, this involves the planting of germinated seeds into black, perforated polybags, usually of size 37.5 x 45.0 cm layflat. If the site is selected, usually on level or gently sloping terrain and near a water source (a river/stream) and space is available, the germinated oil palm seeds, normally at 5-7 days of germination, are planted directly into these polybags. If space is limited, or the nursery site has not been prepared in advance, then a pre-nursery of small polybags of size 15.0 x 22.5 cm can be established, and the seedlings after 10-12 weeks in this pre-nursery are then transferred (transplanted) into the larger (37.5 x 45.0 m) polybags where they can remain for another 9 to 12 months. Temporary shade using attap (Nipa) leaves or nylon netting is usually provided over these polybags for about 10-12 weeks, after which the shade is removed. The seedlings are watered in large nurseries with overhead sprinkler irrigation installed prior to the planting of the germinated seeds, and after the nursery site has been prepared. About 10-25 mm of water are applied twice daily to the seedlings. In some nurseries, the water is applied from extended rubber or plastic hose fitted with a shower head. This is a more temporary measure.

About 10-12 weeks in the nursery, thinning or regueing of the abnormal and runty seedlings is carried out. The abnormal and runty seedlings usually could be easily identified by their abnormal forms and peculiar growth habits. The seedlings are maintained in the nursery for about 10-12 months before they are removed for planting in the field. Prior to their removal for field planting, usually another round of thinning to remove abnormal and runty seedlings is carried out. In well established and maintained nurseries, such abnormal and runty seedlings should not be more than 15%.

Besides watering, maintenance and care of the seedlings in the nursery include manuring and pest/disease control and upkeep of the ground cover. Usually the seedlings in polybags are triangular spaced at a distance of 75 cm. Weeds in the ground and in the polybags are regularly removed, usually manually in the earlier months, at monthly intervals. In a well grown and maintained nursery, disease incidences are usually very low and prophylactic sprayings are not necessary. However, insect pests are more common, especially the cockchafer beetles, and may require spraying for control. Some of the more common diseases in the nurseries are:

a. Blast diseases - Phythium and Rhizotonia

b. Curvularia leaf blight

c. Anthracnose - Botryodiplodia

d. Corticium leaf rot

These diseases would normally be controlled with fungicidal sprayings commonly Thiram, Thibenzole, Captan etc.

The more common insect pests are:

a. Cockchafer beetles - Apogonia and Adoretus

b. Red spider mites - Tetranychus

c. Aphids

d. Crickets and grasshoppers

These insects are usually controlled with insecticidal sprayings, commonly dieldrex, dipterex, Thiodan, Roger, Bidrin etc.

In properly maintained nursery, nutrient deficiencies seldom occur. However, in nursery where sandy soils have been used to fill polybags, the more common deficiencies are those of nitrogen, potassium, magnesium and occasionally boron. Occasionally, toxicity symptoms, due to heavy and excessive fertilizer applications, also occur. The nutrient requirements and their levels for the seedlings in polybag nurseries are shown in Tables 2 and 3 and the common manuring programmes using fertilizer compounds, is shown in Table 4. In a well maintained polybag nursery, seedlings are normally well grown for planting out at 10-12 months.

FIELD PLANTING

Field planting includes the following:

i. Land preparation

ii. Construction of terraces (in hilly terrain), drians (in flat alluvial and swampy situation) and roads and bridges.

iii. Establishment of leguminous cover crops (L.C.C.)

iv. Lining and planting

i. Land Preparation

Methods of land preparation involving clearing and cultivation of land commonly depend on the types and density of the vegetation/crops grown or existing, and the soils and terrain of the land. The vegetation to be cleared may be natural, like primary and secondary jungles or lowland forests or belukar or planted with perennial crops like rubber, oil palm, coconuts or shorter term crops like abaca. Planting ex-jungle, lowland forest or belukar is normally referred to as new planting while planting of ex-rubber, oil palm, coconut and other crops, as replanting.

In new planting, the natural vegetation or timber/ shrubs are first slashed (under-brushing), then felled and stacked and burnt in the drier season, about 6-8 weeks after felling. Sometimes restacking and reburning may be carried out if the initial burn has not been satisfactory. After

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Table 2. Mean Nutrient Concentration in Oil Palm Seedlings at 8 and 14 Months

(Nutrients expressed as % of dry matter)

	N		P		K		Mg		Ca	
	8 mths	14 mths	8 mths	14 mths	8 mths	14 mths	8 mths	14 mths	8 mths	14 mths
Rengam	1.44	0.94	0.20	0.18	1.53	1.22	0.26	0.25	0.20	0.23
Munchong	1.61	1.15	0.19	0.20	1.54	1.31	0.24	0.26	0.18	0.23
Serdang	1.44	1.08	0.20	0.21	1.43	1.33	0.25	0.22	0.20	0.26
No kieserite	1.54	1.07	0.20	0.18	1.53	1.22	0.14	0.11	0.23	0.29
5½ oz kieserite	1.46	1.05	0.19	0.21	1.47	1.33	0.37	0.37	0.15	0.19

Table 3. Average quantiries of major nutrients in oil palm seedlings (gm)

AGE	8 MONTHS	14 MONTHS	INCREMENT
	AMOUNT PER SEEDLING (gm)		
N	2.18	5.16	2.98
P	0.26	0.88	0.62
K	1.87	6.04	4.17
Mg	0.34	1.11	0.77
Ca	0.26	1.11	0.85

Table 4. Manuring schedule for polybag nursery with (A) inland and (B) coastal soil. Quantities of fertilizers in gm/seedling.

GROWTH STAGE	NITRO 26		DOUBLE SUPERPHOSPHATE		MURIATE OF POTASH		KIESERITE	
Before 2 leaf stage			No fertilizer					
2 leaf to 4th month			185 gm Nitrophoska yellow or ammonium phosphate in 4.5 litre water at 115 cc per seedling at weekly intervals					
	(A)	(B)	(A)	(B)	(A)	(B)	(A)	(B)
5 months	3.5	-	3.5	3.5	-	-	-	-
6 months	3.5	3.5	-	-	-	-	-	-
7 months	7.1	3.5	3.5	3.5	7.1	3.5	3.5	3.5
8 months	14.2	7.1	-	-	7.1	3.5	3.5	3.5
T O T A L	28.3	14.1	7.0	7.0	14.2	7.0	7.0	7.0
9 months	14.2	7.1	7.1	7.1	3.5	7.1	7.1	3.5
10 months	-	-	-	-	-	-	-	-
11 months	14.2	14.2	7.1	3.5	14.2	7.1	7.1	3.5
12 months	-	-	-	-	-	-	-	-
13 months	-	-	-	-	-	-	-	-
14 months	14.2	14.2	-	-	14.2	7.1	-	-
GRAND TOTAL	42.6	35.5	14.2	10.6	31.9	21.3	14.2	7.0

burning, roads and terraces and erosion control bunds or structures are constructed. Usually felling of the timber is done by powered chainsaw and stacking and heaping done by machines (bulldozer). The construction of roads, terraces and soil erosion control structures (where slopes exceed 10-12°) is undertaken by machines also. Usually these operations take about 5-6 months to complete, and weather conditions at the time of felling and burning will be critical.

In replanting, the old stands of rubber, oil palm or coconut, are usually destumped and felled by up-rooting with machines/bulldozers. The trunks or stems may then be sawn or cut into smaller lengths stacked in heaps or in rows, and burnt. The old stands of oil palm may be poisoned with sodium arsenite (previously), or paraquat, Prior to destumping and burning Up-rooting or destumping of oil palm and coconut appears to be advantageous because of the more complete or better destruction of the bole and roots, which are substrates for the colonization of Ganoderma root disease organisms and breeding of the rhinoceros beetles (Oryctes), which are serious pests on young oil palms in replantings. In more hilly terrain, where destumping may not be worthwhile or convenient, trees or palms are felled by chainsaw as close to the ground as possible. For the destumping of the old stand, mechanical aids in the form of winches are also employed to pull out the boles/stumps. Trunks and stumps of coconut and oil palm are usually cut into shorter lengths split, stacked and burnt.

On heavy clay alluvial soils, mechanical operations in clearing and destumping may cause soil compaction and it may be necessary to cross plough and harrow the field in order to improve the tilth and at the same time break up the root system of the palm.

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ii. Drainage, Terracing and Roads

On Alluvial soils and other soils of poor and impeded drainage which are subjected to periodic flooding, it is always necessary to improve drainage and aeration. In Peninsular Malaysia, satisfactory drainage can be obtained on marine clays by spacing main drain (5.0 x 1.0 x 3.0 m) at about 1320 m apart with sub or secondary drains (3.0 x 1.0 x 2.0 or 1.5 x 0.5 x 1.5 m) running at right angles to the main drains at 350-400 m intervals.

On shallow peat, less than 90 cm, a system of smaller drains, about 1.0 m deep and spaced at intervals of two to four palm rows, has been found to be more advantageous than a system of deep drains dug at every eight palm row, to avoid rapid shrinkage and accelerated and sometimes irreversible drying.

On undulating and hilly terrain with slope greater than 12°, terracing is necessary. Terraces are usually 3-4 m wide and spaced at 10 m apart, supporting a density of 140 palms per hectare. On steeper slopes and on shallow soils, terracing may be hazardous and less desirable, as the parent rocks or materials (especially sandstone, quartzite or conglomerates) may be exposed. In these areas of lithic soils (lithosols), large platforms (2.25 x 3.00 m) for palm planting should preferably be made together with other soil erosion control structures like silt pits/bunds.

Nowadays, an efficient road system for transport of fruits and communication is absolutely necessary and should be well planned and designed. A general requirement is about 90 m of road per hectare of planted field. This requirement may be increased or decreased according to the terrain and physiographic features and the proximity of the mill/factory. Generally, the more hilly and more dissected the terrain, the greater will be the requiremen for roads, in some cases, up to double the amount.

On peat, although the general intensity of the roa may be maintained, the costs of their construction are greater because of the larger requirement for ballast, stones or other surface and consolidating materials.

iii. Establishment of Leguminous Cover Crops

The planting and establishment of leguminous cover crops is a well recognized and adopted cultural practice in oil palm cultivation because of the substantial beneficial effects from these leguminous covers. Growth and crop yield have both been substantially increased with the planting of these legumes. This is shown in the results of experiments comparing the various ground covers in Table 5. Even on relatively fertile coastal clay, Pueraria and Centrosema covers gave more than 6% higher yields than grasses over 4 3/4 years of harvesting. Much larger responses have been obtained with these covers in plantings on inland soils.

Table 5. Effects of covers on fruit bunch production over 2½ - 7¼ years of young palms on marine clay (t/ha)

	WITH FERTILIZER	NO FERTILIZER	AS % OF LEGUME COVER PLOT	
			WITH FERTILIZER	NO FERTILIZER
Grass	110.8	110.9	92.4	92.5
Mikania	106.5	94.1	88.8	78.8
Nephrolepsis	116.7	103.3	97.3	86.1
Pueraria-Centrosema	119.9	117.8	100	98.2

The mixture of leguminous covers which are commonly being planted are;

Pueraria phaseoloides	2.0 kg/ha
Calopogonium caeruleum	1.0 kg/ha
Calopogonium muoncoides	1.5 kg/ha
Centrosema pubescens	0.5 kg/ha
	5.0 kg/ha

These legumes are usually sown in drills spaced at 1.5-1.8 m apart, between the palm rows, with additional drills sown at right angle to these drills. On contoured land, the seeds are sown between terraces. Seeds are usually pre-heated or scarified and mixed with rock phosphate (usually CIRP) and inoculated with Rhizobium, (10 gm to 10 kg seed) before sowing. The germinating L.C.C. are kept weed free by clean weeding either manually or with herbicidal sprayings (recently) at fortnightly intervals initially for the first three months, after which they are weeded at monthly intervals until they are fully established.

To encourage their establishment and development, the L.C.C. are normally manured with a starter dose of compound fertilizer (nitrophoska 15:15:6:4), two-three weeks after germination, at the rate of 30 gm per 6 m drill, and at a rate of 60 kg/ha, of rock phosphate (boradcasted) 3 and 6 months after sowing. Further applications of rock phosphate at rates of 150-250 kg/ha are made at annual intervals for the subsequent two years.

Insect damages on germinating drills of the L.C.C. and during subsequent years after initial establishment may be quite serious, especially in new plantings (probably due to starvation of the insects after burning of the vegetation). Most common of these are the caterpillars (Lamprosema), beetles (Pagria, Epilachna) and grasshoppers. Snails and slugs can also cause severe defoliation damages. The caterpillars, beetles and grasshoppers may be controlled with the common insecticides, Bidrin, Servin (Carbaryl) and other chlorinated hydrocarbons, while snails and slugs can be controlled with metaldehyde baits at 25 kg/ha.

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Diseases of the L.C.C. are usually less common. Rhizoctonia solani seems to attach Puereria and Calopogonium more often during prolonged wet weather. Control measure involves spraying affected patches with 0.2% ferbam or Thiram.

iv. Field Planting

The seedlings are normally field planted at the age of 12-14 months when two-stage nursery is used, and 10-12 months when a single-stage nursery (planted directly into large polybags) is used. A final round of rogueing and removing of abnormal and runt seedlings is usually carried out prior to field planting. These seedlings may be lightly pruned to facilitate their lifting and loading onto vehicles and plantings in the field.

Holes as large as or slightly larger than the size of polybags are dug before planting the seedlings in them. About 200 gm of rock phosphate, usually CIRP, are first applied into the planting holes. The seedlings are then placed upright in the holes, the polybags are then split and the polythene removed and the holes are then filled with soil until the palm bulbs are level with the ground. The soil beneath is consolidated fairly firmly and the top (surface) should be more firmly packed. The polythene (of the polybag) may sometimes be placed around the palms, to serve as mulch and as a mark of planting.

In the fields, the seedlings are normally planted at a density of 148 per hectare. The fields are lined at a triangular spacing or system prior to planting, and each planting point is marked with a bamboo stick, which is usually top/tip painted (red or white) for easy aligning and checking.

In recentyears, increasing attention has been given to the density and stand of palms after maturity. It has been observed that some planting materials, under more favourable environmental conditions or better standards of management and maintenance, showed marked differential growth at the density of 148 palms per hectare. Inter palm competition with these planting materials becomes evident at 8 or 9 years after planting, and trunk etiolation and reduction of crop become increasingly severe after the 12th to 13th year. It has become increasingly apparent that it will be necessary to study in much greater detail the interaction of density and environment and genetic materials, and the adaptation of various genetic materials to varying environmental conditions in space and time. For the time being, it would appear that the optimal density of oil palm under more favourable environmental condition and better maintenance in Malaysia may fall below 130 palms per hectare after the 14th to 15th year of planting.

CULTURAL/AGRONOMIC PRACTICES

Operations after planting of the seedlings in the field are normally considered as husbandry, and main cultural practices in the oil palm plantation are:

a. Weed Control
b. Pest/Disease Control
c. Ablation
d. Assisted Pollination
e. Pruning
f. Harvesting
g. Manuring

a. Weed Control

This is to establish and maintain a ground cover condition or system which is most conducive and favourable to the establishment and growth of the oil palms. In

Malaysia, this means the care and up-keep of the planted leguminous cover crops, removing all competitive weeds amongst the 'sward' in the initial years (about 4 years) and eradicating all noxious, coarse and competitive weeds (grasses, woody and herbaceous plants and creepers) in the subsequent years. Some of the more common noxious and competitive weeds are the Imperata cylindrica, Ischaemum spp., Panicum nodosum, Mikania scandens, Eupatorium odoratum, Melastoma spp. and Clademia spp. These weeds are usually controlled by spraying with various appropriate types of herbicides that are well represented.

Some of the common herbicides used are dalapon, glyphosate, 2,4 D-amine, MSMA, diuron, paraquat (gramoxone) and sodium chlorate. In cocktail mixture or in sequential programmes, these herbicides have been used to control weeds in the palm circles (usually 1.0-1.5 m radius) and harvester paths (1.5-2.0 m width), roads and drains (side) and in selective spraying programmes to remove the most noxious weeds normally in the first 2 years after field planting and in fields in which leguminous cover crops have been established. The palm circles are kept clean and weed free by monthly to bimonthly manual weeding. Subsequently, the palm circles are maintained with herbicidal spraying and the vegetation in the interrows or avenues are controlled by selective spraying or weeding to remove the more competitive weeds and woody plants.

In recent years, interests have been generated in the use of biological control of the competitive weed viz, Mikania scandens. The possibility of employing the natural insect predators (Acalitus, Liothrip, Teleonemia, Apion) to control these very competitive creepers is being examined and considered.

When the canopy of the crown closes, usually at the 5th or 6th year after planting ground cover vegetation usually becomes sparse and comprises only the shade tolerant species, which are usually soft and less competitive. These are checked and controlled with two or three rounds of herbicidal sprayings per year.

Much concern has been shown in the use of hormonal types of herbicides and glyphosate in young plantings. The use of formulation containing 2,4 D-amine and 2,4,5-T and glyphosate on palms younger than three years in the field is avoided or prohibited, since severe damage on the palms in the form of malformation and retarded emergence of the young leaves have been frequently experienced with these herbicides. However, palms older than three years and those which are well grown and robust, could tolerate and withstand the phytotoxic effects of these herbicides (within the normal and recommended rates of application of these herbicides).

Dense epiphytic vegetation on the trunks of the mature oil palms are also occassionally controlled with herbicidal spraying, usually one round in a year. Care should be exercised in these sprayings not to damage developing inflorescences with the herbicides.

b. Pests and Disease Control

The more common pests of the field palms and their control are shown in the Table 6 below:

Table 6. Common Pests of Oil Palm and Their Control

1. Insects		
a. Night flying beetles (Apogonia and Adoretus)	Eat green leaves	Lead arsenate spraying 0.36-0.60% or Dipterex (0.1%)
+b. Cockchafer grubs (Psilopholis vestita)	Feed on root system, ultimately killing palm	Rotavate and drench soil with 0.5% a.i. of Aldrin, Heptachlor or Telodrin
c. Hispid leaf miners (Coelaenomenodera)	Destroy leaf tissue	BHC dust

Table 6. (continuation)

d. Rhinoceros beetles (Oryctes)	Attack young and spear leaves leading to bud rot	Control by eradicating breeding sites and grubs
e. Bagworms (Metisa and Cremastopsyche spp)	Eat leaf tissue	Srpay with Dipterex at 1-1½ kg/ha. is preferable to lead arsenate
f. Nettle caterpillars (Setora and Ploneta spp)	Eat laminae leaving mildribs only	Lead arsenate at 4 kg/ha or Dipterex at 2 kg/ha
g. Grasshoppers (Vallanga)	Cut out edges of pinnae	Lead arsenate at 4 kg/ha or spray with or dieldrin
h. Bunch moth (Tirathaba)	Feed on mesocarp and kernel	Spray with Dipterex - 0.5 kg/ha and Thiodan
2. Rodents		
a. Porcupines	Eat out apical bud	Bait with zinc phosphide/ coconut or flour
b. Rats	As above	Bait with mixture containing rice bran and Warfarin or Tomorin. Also use protective wire collar
3. Mammals		
a. Elephants	Feed on the young cabbage and tender shoots; destroying the palm by pulling the spear or felling it	Shooting and hunting. Use of electric wire in fencing the boundary, construction of large trenches or ditches to surround the boundary.
b. Cattles and water buffalo	Grace on the leaves and tender spears	Heding and patrolling to chase and keep away these animals
c. Squirrels	Feed on ripening fruits	Not serious and no control measures taken at present. Shooting, poisoning and trapping may be possible control measures.
4. Birds		
a. Parakeet	Feed on ripening fruits	Not serious and no control measures taken at present. Shooting, poisoning and trapping may be possible control measures.

+These are in South America and Africa

There are more common diseases of the field palms and and their control are shown in Table 7 below:

Table 7. Common Diseases of Oil Palm and Their Control

1. Leaf Diseases and Disorder		
a. Crown disease Usually on 2-3 years old palms	Casual agent not known but genetical differences in susceptibility observed. Fungi associated are mainly Fusarium	Removal of diseased spears by cutting followed by spraying with 1.0% Thiabendozol solution. Planting of more resistant materials
b. Spear rot-Bud rot complex Usually on 2-5 years old palms	Causes not known but are probably associated with pathogenic microbes gaining entry by prior physical/mechanical damage of the tissue/organs with vector insect and suffering physiological stress	Removal of diseased spear or drenching the cabbage with a fungicide
2. Stem/Trunk Disease		
a. Upper stem rot Usually on palms older than 10 years	Caused by pathogenic fungus Phellinus noxious, (Fomes noxious)	If the disease could be detected early (by sonic means) trunk surgery to excise all diseased tissues and painting the exposed healthy tissues with preservations or wound dressings.
3. Root Disease		
a. Basal stem rot (Ganoderma) Usually on palms older than 10-15 years but 5-6 years palms are also affected	Caused by pathogenic fungus Ganoderma spp	Destruction of all infected tissues and of the root system of the old oil palm or coconuts. No effective method of control of the palms infected with this disease known.
b. Dry basal rot (Ceratocystis paradoxa) Usually on 5-7 years old palms	Caused by pathogenic fungus Ceratocystis paradoxa	No known treatment. Dead palms removed.
c. Stem wet rot Usually on 3-10 years old palm	Associated with a disease infection of the root; possibly of bacteria or virus or mycoplasma-like organism and unfavourable wet soil water regime	No known treatment Drainage and eradication of grass covers have been suggested.

Ablation or Castration

The removal of young inflorescences and bunches as soon as these emerged or formed when the palms commence flowering has been termed ablation or disbudding or castration. Young palms usually commence to flower at about 10-12 months after field planting and ablation is usually carried out at monthly intervals from the 14th to 27th month. This practice has become quite common in the oil palm cultivation in Malaysia mainly because of the following advantages:

i. improved vegetative growth and those of the root system by channelling assimilates and metabolites to these vegetative organs/parts,

ii. encourages a more uniform stand and establishment of the planting;

iii. more effective in the conrrol of bunch rot diseases (Marasmius) and of attack by Tirathaba caterpillars;

iv. higher yield at the commencement of harvesting with larger and better formed bunches with higher oil to mesocarp content;

v. Better tolerance to attack of pests and diseases due to the improved growth and vigour.

Probably due to varying duration and time of commencement of ablation and also to the irregularity in the programme, responses to ablation in term of higher bunch production and improved growth and vigour were not consistent or as significant in some oil palm plantings as those achieved in some of the experiments conducted to investigate this practice. Timing of the programme to coincide with the better rainfall and climatic condition has also been shown to be critical in ensuring and sustaining higher initial bunch production. It has also been suggested that the practice of ablation is of more practical utility in region of low than high production and particularly so in extremely dry condition such as obtained in West Africa in which there was evidence of improved drought resistance due to improved vegetative development, including the root system. This practice should be considered for adoption in areas of poor soil conditions or poor growing conditions and drier climatic zones.

d. Assisted Pollination

This refers to artificial pollination of the female inflorescences manually or mechanically. This has become necessary especially in new areas of oil palm cultivation in which the rainfall is excessive; exceeding 2,500 mm annually and in which there are no older oil palm plantings in the vicinity. Inadequate natural pollination due to the production of higher number of female inflorescences (higher sex ratio) of the improved planting materials at the earlier years and to the slow increase in population of the pollinator insects - until recently, mainly thrips in oil palm plantings - and to the heavy precipitation prevailing in the monsoon seasons have been the causes of poor fruit formation and production in Malaysia, especially in East Malaysia (Sabah and Sarawak). The necessity of assisted pollination has apparently been established by a series of experiments conducted in Malaysia in the 1950-1960, and until recently assisted pollination with puffers, lance applicators and mechanical dusters has been a routine practice in all oil palm plantations in Malaysia. Pure pollens collected from the male inflorescences, either alone or mixed with talcum powder in a ratio varying from 1:4 to 1:10 by weight, have been used and applied at regular intervals of one every three days on palms from the third year to the eighth or ninth year from planting with the planting materials presently used.

The natural pollinator weevils Elaeidobius spp were studied and introduced into Malaysia from Cameroon, Africa a few years ago. Following fairly detailed studies on the host specificity and their responses to the local environme these weevils mainly Elaeidobius kamerunicus, were released and are now well spread over Malaysia. Over the last year or so after their release, the weevils have been observed to breed and survive well under the Malaysian climatic condition and have not been inhibited, restricted or checke in their pollination activities. These pollinator weevils are observed to be very efficient in their pollination activities, and bunch formation and thus crops or yield in most of the oil palm plantations, especially those in East Malaysia, have increased substantially; by as much as 40-60% or 6.0-8.0 tonnes of fruit bunches per hectare, and bunch weight increases of over 2.50 kg each. Crude palm oil and palm kernel production in Malaysia has increased by about 24.0% and 54.0% last year (1982) to reach 3.5 million tonnes and over 900,000 tons respectively. It has been suggested that a substantial share of such increases has been attributed to these weevils. However, it remains to be seen whether these beneficial effects and contribution of these weevils over the lon-er term or in the near future could be sustained, since results of experiments on intensive pollination (assisted) have shown that appreciable abortion of the inflorescences an bunch failure followed the initial high increase in fruit bunch production; from the 40 months and thereafter.

The immediate concern and consideration are the nutrien drain and stress imposed by such large increases in the crop or fruit bunch production. It seems likely that in oil palm

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plantation with marginal nutrient condition, such a stress could be expected and significant depletion and deterioration in the nutrient condition may be anticipated.

e. Pruning

Pruning of leaves is also a common practice in oil palm cultivation and usually commences four or five months before fruit harvesting begins when young palms reach the age of about 32-36 months after planting. Pruning may commence earlier, at about 18 months, to facilitate circle weeding, ablation and pest/disease control. Leaf pruning is carried out to:

i. facilitate circle weeding, ablation, assisted pollination and pest/disease control;

ii. facilitate harvesting and viewing of bunch ripeness;

iii. reduce the accumulation of rotting palm materials and lodging of fruits in the trunk wh would encourage the growth and establishment of epiphytic plants which may cause difficulty in viewing and inspecting of the ripening bunches.

iv. Possibly improve aeration and evaporation in the field.

First systematic pruning is usually carried out whc the lowest ripe bunch is about 60 cm above the ground. Subsequently, pruning is carried out at intervals of four to six months. All experiments on frond pruning and retention indicate that maximum yield are obtained by retaining as many green and functional leaves as possible, but the differences in yields in retaining more than 40 leaves in mature oil palm planting are usually small. However, severe pruning, leaving less than 32 leaves, has a rapid and serious depressive effect on bunch production and yields could be reduced by more than 25%, and bunch weight (size) may be reduced after four months and bunch production dropped after eight months. This has been accompanied by increase in abortion rate of the inflorescences

It is common to prune to leave at least a whorl of leaves below a ripe bunch, with preference to leave 2 whorls of leaves below the bunch. This would leave about 40 leaves on the palms at any time. Timing of pruning may also be important in seasonal climate. It has been suggested that pruning at the beginning of wet season should be avoided.

In pruning, the leaves are cut as close to the trunk as possible with chisels or axes and in older palms with sickles (Malaysian knife) attached to the bamboo pole. However, care should be taken in pruning close to the trunk to avoid damage to the still younger leaves.

f. Harvesting

With most of the precocious materials presently planted, harvesting could commence after 2½ years of planting and usually at 32-34 months in fields well established and maintained. In poorer plantings, harvesting may be delayed to 3½-4 years.

With Elaeis guineensis var nigrescens, as the fruit in the bunch ripens, the colour changes from deep purple or black to reddish orange and the oil content increases in the process. When the oil content reaches maximum, the fruits become loose and fall to the ground. Because of uneven ripening, it takes about 10-20 days for all fruits in a bunch to ripen. The fruit bunch has to be harvested either in an under-ripe nor over-ripe condition. Until now there is no exact criterion for optimal ripeness and it is common practice to harvest when there are two loose

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fruits on the ground per estimated kilogramme of bunch weight, e.g. 25 loose fruits for a 12 kilogramme bunch.

Ripe bunches are cut with chisels or axes or knives on bamboo poles, depending on the height of palm. Generally harvesting starts with chisel and is continued as long as practically possible; usually until 8 to 9 years and thereafter with curved knives on bamboo poles and care must be undertaken not to damage any functional green leave immediately around and above the ripe bunch to be harvested. Leaf subtending the ripe bunch to be harvested is usually cut at the same time, and the cut leaves are normally stacked in the interrow/avenue.

Harvesting interval is normally 10 to 12 days in the early years and subsequently, 7-10 days provided that harvesters are available. Acute shortage of harvesters is presently being experienced in Malaysia and under this situation, harvesting intervals have invariably been extended to 12-14 days or even longer.

Cut bunches and loose fruits are collected and carried in bamboo baskets to a collection point or platform near the roadside. On more level terrain, wheelborrows are becoming more popular. Use of drought animals mules (in South America) or waterbuffalo (in Malaysia), has also been made in some plantations. Mechanized harvesting and collection of fruit bunches are being developed and are receiving increasing interest and attention.

From the collection point or platform, fruit bunches and loose fruits are transported to the factory/mill by a number of ways, depending on the initial planning on the infrastructure development. The more convenient and common system involves road transport by trucks, tractor/trailer and lorries fitted with hydraulic system for lifting and unloading (or tipping of the load) of the fruits. Fruit transport by road using trucks or lorries has become increasingly popular due to the reduction in labour requirement and to the convenience of weighing the harvested crops.

Manuring

The oil palm requires large quantities of nutrients, both macro and micro elements, for growth and reproduction. Manuring and fertilizer applications are important and necessary cultural practices to ensure and to maintain good growth and crop production in oil palm cultivation. Even on the relatively fertile environmental and soil conditions in Malaysia, applications of fertilizers and their requirement constitute over 40% of the total annual field production costs.

Various estimates of the nutrient requirements and uptake of oil palms have been carried out in different oil palm growing countries. In Malaysia, the estimates of total nutrient uptake by 148 palm per hectare per annum are shown in the following Tables 8, 9 & 10.

More recently, the requirements of anionic nutrients, especially of chlorine and sulphur have received attention. Although the contents of these elements, in the leaf have been analysed, estimates of these nutrients in the whole palm and in the fruit bunches have yet to be made.

The common technique in assessing the nutrient requirements and fertilizer needs of the oil palm in Malaysia is foliar analysis. This plant tissue analysis of leaf No. 17 in mature palms and of Leaf No. 3 or 9 in young palms has received considerable research efforts and studies to establish the relationships of the nutrient contents in the leaf with growth and yield and their uptake in the palms. Sampling techniques and procedures to study

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the sampling error, intensity and seasonal variation of major nutrients have been studied and investigated and results of these studies, together with those from manurial experiments, have generally confirmed the preference of this technique for assessing the nutrient requirements of the oil palm. Positive and significant correlations of the nutrient levels with growth and yield of the oil palms, especially those of major nutrients viz, nitrogen, phosphorous and potassium, have been obtained and achieved.

The tentative criticallevels of the nutrients presently being employed for nutrient assessments are as

Table 8. Estimates of total nutrients uptake by 148 palms per hectare per annum

COMPONENT	N		P		K		Mg		Ca	
	kg	%	kg	%	kg	%	kg	%	kg	%
1. Net cumulative vegetative matter	40.9	21.2	3.1	11.9	55.7	22.2	11.5	18.8	13.8	13.9
2. Pruned fronds	67.2	34.9	8.9	34.2	86.2	34.3	22.4	36.5	61.6	61.9
3, Fruit bunches (25 tonnes)	73.2	38.0	11.6	44.6	93.4	37.1	20.8	33.9	19.5	19.6
4. Male inflorescence	11.2	5.9	2.4	9.3	16.1	6.4	6.6	10.8	4.4	4.6
T O T A L	192.5	100	26.0	100	251.4	100	61.3	100	99.3	100

(26.0 kg P = 59.5 kg P_2O_5, 251.4 kg K = 302.8 kg K_2O)

Table 9. Estimated annual uptake of micronutrients by 148 palms per hectare per annum (gm)

COMPONENT	B	Cu	Zn	Mn
1. Cummulative vegetative matter	50.32	48.84	226.44	467.68
2. Pruned leaves	125.80	88.80	177.60	2,960.00
3. Fruit bunches	53.28	116.92	121.36	372.96
T O T A L	229.40	254.56	525.40	3,800.64

Further, the nutrients removed or contained in 10.0 tons of fruits bunches has also been estimated and are as foolows:

Table 10. Estimates of nutrients removed in 10.0 tons of fruit bunches

PER TONS OF BUNCHES	N	P	K	Mg	Ca	Mn	Fe	B	Cu	Zu	Mo
Kilogrammes	29.4	4.4	37.1	7.7	8.1						
Grammes						15.1	24.7	21.5	47.6	49.3	0.084

Table 10.1 Tentative critical levels of nutrients employed for nutrient assessments

NUTRIENT	N	P	K	Mg	Ca	Cl	S	Mn	B	CU
	% on dry matter							ppm		
Leaf No. 3	2.80–3.00	0.18–0.20	1.30–1.50	0.30–0.35	0.30–0.50		–	–	–	–
Leaf No. 17	2.70–2.30	0.16–0.18	1.00–1.20	0.20–0.25	0.45–0.55	0.30–0.50	0.20–0.24	200–250	10–12	2–4

Table 11: Rates and Types of Fertilizer Application for Oil Palm in Malaysia

Rates of Sulphate of Ammonia (N) and Muriate of Potash (K) recommended for young plantings on four major soil groups in West Malaysia (kg/palm)

YEARS IN FIELD	I. Sandy loams to sandy clay from granite, sandstone, older alluvium		II. Clay from basic igneous rocks		III. Silty clay from shales		IV. Marine clays	
	N	K	N	K	N	K	N	K
1.	0.68	0.45–0.90	0.45	0.66	0.45–0.68	0.45	0–0.23	0
2.	0.90–1.36	1.36–2.50	0.68–0.90	1.36–1.60	0.68–1.36	1.14	0–0.23	0.45–0.68
3.	0.90–1.36	2.27–3.41	0.68–0.90	2.04	0.68–1.36	1.60–2.04	0–0.23	1.14–1.60
4.	0.90–1.60	2.73–3.86	0.90–1.14	2.04–2.73	0.90–1.60	2.04–2.73	0–0.23	1.14–1.60
5.	1.14–1.81	2.73–3.86	0.90–1.14	2.73	1.14–1.81	2.04–2.73	0–0.23	1.81–2.04
6.	1.14–1.81	2.73–3.86	1.14–1.60	2.73	1.14–1.81	2.04–2.86	0.90–1.14	1.81–2.04
7.	1.81–2.04	2.73–3.86	1.60	3.41–3.64	1.60–2.04	2.73–2.86	0.90–1.60	1.81–2.73
8.	1.81–2.73	2.73–3.86	1.60	3.41–3.64	1.60–2.73	2.73–2.86	0.90–1.60	1.81–2.73

Source: Hew and Ng

Table 11.

Rates of Christmas Island Rock Phosphate (P) and Kieserite (Mg) recommended for West Malaysia (kg/palm)

YEARS IN FIELDS	I. Sandy loams- sandy loams from granites, sandstone and older alluvium		II. Clays from basic rocks		III. Silty clay loams- silty clays from shales		IV. Marine Clays	
	P	Mg	P	Mg	P	Mg	P	Mg
1.	0.45-0.90	0.23-0.45	0.23-0.45	0.23	0.45-0.90	0.23	0	0
2.	0.68-1.[illegible]	0.45-1.14	0.23-0.45	0.45	0.45-0.90	0.45	0	0
3.	0.68-1.60	0.90-1.14	0.45-0.68	0.45-0.68	0.68-1.60	0.68-0.90	0	0
4.	0.90-1.60	0.90-1.60	0.90-1.14	0.68-0.90	0.90-1.60	0.90-1.14	0.23-0.45	0-0.23
5.	1.14-1.60	1.14-1.60	0.90-1.14	0.68-0.90	0.90-1.60	0.90-1.36	0.23-0.45	0-0.23
6.	1.14-1.60	1.13-1.81	0.90-1.14	0.90-1.14	0.90	1.14-1.36	0.23-0.45	0-0.23
7.	1.14-2.04	1.36-1.81	1.14-1.36	0.90	1.14-2.04	1.14-1.60	0.45-0.90	0-0.45
8.	1.60-2.04	1.36-1.81	1.14-1.36	0.90	1.36-2.04	1.14-1.60	0.45-0.90	0-0.45

Source: Hew and Ng

it has also been observed and experienced that levels of major nutrients, expecially of nitrogen and potassium seem to decline with age of the palms and are also related to soil water regime. Thus, it is not uncommon to observe lower nitrogen and potassium levels in palms older than 15-18 years and in palms growing on alluvial soils (on the marine/riverine alluvial). There are also indications that nutrient levels could also be related to the genetic materia

The common types and rates of fertilizers applied to oil palm in Malaysia are shown in Table 11.

More recently, in the last few years (1984), the results of a large experiments on manuring oil palms in differing soil and climatic environments and the yield responses of fruit bunch production to the fertilizer applications, especially of nitrogeneous and potash fertilizers, have been studied by the Palm Oil Research Institute Malaysia (Foster, Mohamed, Chew et al. 1984). Response equations were fitted to the yield of fresh fruit bunches to the application mainly of nitrogeneous and potash fertilizers at non-limiting levels of other nutrients. It was found that on all soils, responses were found to be related to yield level and to soil moisture condition after fertilizer application. Yield responses to potash fertilize was also found to be dependent on the potassium buffering capacity of the soil, whilst response to nitrogeneous fertilizer increased with clay content of alluvial clays and decreased with the slope on sedentary soils. In the absence of potash fertilizer, yields were significantly related to the drainage condition, hot acid extractable potassium content, average soil moisture content of the alluvial soils and to drainage condition, exchangeable potassium and organic matter of the sedentary soils. In absence of nitrogeneous fertilizer, yields were related to drainage condition and rainfall on alluvial soils and to palm age, planting density, soil consistency and leaching intensity on sedentary soils.

Basing on these responses studies, the yield of fruit bunches and the fertilizers (nitrogeneous and potash) requirement have been predicted on the major soil types in Malaysia. These fertilizer requirements and predicted yields are shown below.

SOIL SERIES	FRESH FRUIT BUNCHES TONS/HA PER YEARS		FERTILIZER KG PER PALM PER YEAR	
	WITHOUT FERTILIZER	WITH FERTILIZER	S/A	MOP
Rengam (fine, kaolinitic isohyperthermic, Typic Paleudult)	20.4	28.5	4	6
Munchong (Very fine, clayey, kaolinitic isohyperthermic, Typic Acrorthox)	24.1	25.5	1	1
Batu Anam (clayey, mixed isohyperthermic Aquoxic Tropudult)	15.2	23.6	5	5
Briah (Very fine, mixed, isohyperthermic, Typic Tropaquept)	23.3	26.6	4	0
Selangor (Very fine, mixed, isohyperthermic Aeric Tropaquept)	25.2	25.8	1.5	0

Another recent estimates on the nutrient inputs (Ng and Thong, 19[illegible]) for achieving the yield potentials of oil palms have been also been given and these are related to the taxonomic units (sub-group) of the soils occurring in Malaysia. These nutrients requirements are shown below together with the relevant analysis data.

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Nutrient inputs for achieving yield potentials in oil palm (kg/palm/yr)

SOIL	N	P	K	Mg	B_2O_3	CuSO4
Typic Tropopsamment	1.15-1.40	0.32-0.37	2.25-2.75	0.16-0.22	0.10-0.12	NIL
Oxic Paleaquult	1.20-1.50	0.22-0.27	1.50-1.80	0.10-0.13	0.08-0.10	NIL
Typic Paleudult	1.00-1.25	0.25-0.30	2.00-2.50	0.12-0.15	0.05-0.07	NIL
Aeric Tropaquept	0.45-0.60	0.00-0.15	0.80-1.00	0.0	0.03-0.05	NIL
Typic Tropofibrist	0.30-0.45	0.00-0.15	3.00-3.60	0.0	0.12-0.14	0.001 (F)

Soil Analysis Data of Soil Evaluated

SOIL	HORIZON (cm)	pH	C%	N%	P (ppm)		EXCH. me %			6NHC1 K me%	% CLAY	% SILT
					A	T	K	Mg	Ca			
1. Typic	0-15	4.5	2.00	0.17	24	104	0.10	0.17	0.47	1.41	54.8	10.3
Tropaquult	15-30	4.5	0.87	0.14	21	176	0.20	0.38	1.36	1.36	47.6	19.8
	30-45	4.5	0.72	0.08	7	119	0.09	0.15	0.39	1.47	47.6	18.2
	45-60	4.4	0.66	0.09	13	152	0.11	0.22	0.55	1.58	50.6	14.6
2. Typic	0-10	4.8	2.32	0.29	30	153	0.05	0.	0.52	0.17	23.1	6.1
Troposamment	10-40	[illegible]	0.80	0.18	16	111	0.03	0.07	0.27	0.21	25.2	6.1
	40-60	5.0	0.81	0.07	22	117	0.06	0.08	0.38	0.20	28.3	5.9
3. Typic	0.12	4.3	1.13	0.44	21	139	0.08	0.16	0.41	1.12	31.9	3.2
Paleudult	12-30	4.4	0.44	0.30	14	104	0.05	0.06	0.38	1.24	32.8	1.5
	30-60	4.4	0.23	0.17	16	126	0.08	0.08	0.41	1.91	35.5	2.0
4. Aeric	0-12	4.4	4.31	0.42	54	350	1.70	3.22	1.72	4.50	41.1	43.9
Tropaquept	12-30	4.0	2.29	0.19	40	283	0.56	1.63	0.86	4.56	43.6	48.6
	30-60	3.8	1.10	0.09	26	302	0.39	4.49	0.84	6.24	58.7	36.9
5.												
											(L1%)	
5. Typic	0-15	3.75	39.3	1.77	22	376	0.32	1.55	1.17	0.61	81.9	
Tropofibrest	15-30	3.85	43.5	1.67	40	223	0.12	0.35	1.13	0.43	88.3	
	30-60	[illegible]	44.0	1.31	[illegible]	131	[illegible]	.35	[illegible]	.30	[illegible]	
	60-90	[illegible]	39.1	1.21	15	145	0.11	0.35	0.69	0.43	[illegible]	

Reference: A = Available

T = Total

L1 - Loss on Ignition

The fertilizer programmes could be applied with mixture of straights, or with blended or chemical compounds containing more or less the same quantities of nutrients. In practice, since most of the blended or chemical compounds do not contain the large requirement for potash and kieserite and trace elements, applications of such compounds have to be often supplemented with muriate of potash, kieserite and trace element fertilizer. Use of mixtures of these straight fertilizers is more convenient and is frequently cheaper.

Fertilizer programmes are commonly split into two or three rounds of applications, with applications timed to avoid the very dry and very wet seasons. In younger plantings of less than four years grown on more sandy or shallow soils, frequency of application is increased to four or six rounds in a year.

Placement of fertilizers is usually related to zone of high root activities and densities. For the immature palms of less than 2 years, placement near the palm base, in circle band between 1.0-2.5 m of the base is the most effective. For palms three years and older, this should be 2.0-4.0 m and for palms over eight or nine years, placement could be extended to the avenue or interrow, since the root system is then well distributed. However, it is common to apply fertilizers within a circle of radius of 3.0-5.0 m for the purpose of supervision. On flat and level land, mechanical application of fertilizer is being carried out, while in hilly land, the fertilizers are naturally applied along the terraces, usually at the back of the terraces.

Shortages, especially acute and demanding of nutrients are fairly well reflected in define symptoms of deficiencies. The most common of these are deficiencies of nitrogen, potassium, magnesium, boron and copper. The symptoms of these nutrient deficiencies are fairly well described and are easily recognizable. However, when such nutrient deficiencies become visually distinct and recognizable, the deficiencies are already in fairly advanced stage and the needs for fairly large amounts of fertilizers for correction and amelioration of these deficiencies have well been demonstrated.

Soil analysis for assessing fertilizer requirements of oil palms has been less popular and less preci se then the foliar analysis. This is mainly due to difficulty of corre- lating soil fertility with nutrient uptake and growth factors. The difficulty is due to that fact that (i) roots extract nutrients from three sources; the soil solution, the xchangeable ions and the readily decomposable minerals f the soils which are interrelated in a complex manner; (ii) a measure of any of these sources may not indicate the eal availability of nutrients since soils differ in the ate at which they release exchangeable ions; (iii) the ooting volume of the oil palm is large and thus, sampling s difficult; (iv) the oil palm, being a perennial, can ake up nutrients released by slowly weathering minerals nd stored these in the large trunk and other organs. (v) physical condition of the soil such as soil structure, oil moisture regime and depth of solum also influence, ometimes greatly, the availability of the nutrients and he ability of the roots to exploit and extract these utrients. Nevertheless, significant correlations and elationships have been found and established between otassium mole fraction (Excha. K/CEC) and yield of fruit unches in Nigeria. This relationship was further improved hen the activity ratio in which activities of K, Mg and Ca nd Al were taken into account was used. It was then found hat potassium response was closely related in the following

$$AR = \frac{K_e}{Ca_e + Mg_e + 2.5\,Al_e}$$

where e = exchangeable

If the mole fraction was 0.015-0.020, K status was probably marginal and when it was less than 0.015, a likely response was expected. An activity ratio of 0.006 was considered critical.

Correlations have also been found on Acid Sands soils in Nigeria in which response to exchangeable K were obtained when this falls below the ragne of 0.10-0.20 meg per 100 gm. Relationship between water soluble magnesium, in the top-soil and both deficiency symptoms and leaf Mg were also found in Congo in soils in which the exchangeable Mg was below 0.10 meg per 100 gm and a critical Mg:K ratio of about 2 and below.

In Malaysia, although a considerable body of soil analytical data has been accumulated, there are no detailed and thorough studies on the relationship of soil nutrients and oil palm yields and the nutrient levels in the leaf. Some studies have been undertaken but no clear or significant relationship could be established, probably due to the generally better manurial practices in the plantation industry. However, the general pattern of the nutrient status of the soils in Malaysia could be described as follows:

i. The generally higher nutrient status of the marine clays on the west coast of Peninsuler Malaysia, particularly in P, K and Mg and occassionally N.

ii. The very low K and Mg reserves in soils derived from granites, sandstones and quartzites, older and sub-recent alluvial sediments.

iii. The very low K status of soils derived from basalts and andesites.

iv. The variable but higher status of K of soils derived from shales.

v. The very low N and P status of soils derived from pale coloured shales.

vi. The extreme acidity of acid sulphate soils and low K and Mg status.

vii. The generally low N and P status of most inland soils derived from acid igneous and sedimentary rocks, and the higher P status of soils derived from basic rocks.

Although measures of exchangeable cations have been widely used to indicate nutrient status, it has been found in Malaysia that differences between soil types in this respect are not very great although the total cations are sometimes considerable. Hence, the general pattern of fertility of the soils in Malaysia, as indicated above, has been observed. In regions where large areas are covered with soil of more or less the same origin, some correlations can be found. However, in areas where changes in soil type are abrupt with marked changes of underlying parent rocks, limited use can be made of analytical data. Nevertheless, in any feasibility study of oil palm development in new areas, regions or countries, soil suitability classification with field and laboratory data from soil survey is an essential and sometimes decisive component. The knowledge and the interpretation of these field and laboratory data in relation to oil palm growth and production requirement are the exercise and the objective of this exercise.

Agronomic Classification of Soils for Oil Palm Development

The main characteristics and properties used to classify soils for oil palm development are:

i. texture

ii. quantity of gravel or stones

iii. water permeability or lack of drainage

iv. chemical composition

The broad and general suitability classification is shown below:

Table 12. Soil Classification for Oil Palm

CLASS	TEXTURE	GRAVELS AND STONES	DRAINAGE	CHEMICAL STATUS
I	Sands to clays	None	Good	Organic-good Exch. cation - good
IIa	Sands to clayey	None or very little	Good to 90 cm	Organic - medium Exch. cation - medium
IIb	Sands to clays	Some gravel	Good to 60 cm	Exch. cation - medium
III	Sands to clays	Gravelly	Poor	Organic-medium Exch. cation - poor
IV	Leached sand or very heavy clay	Very gravelly	Deep peat or very bad	Poor

It will be seen that in this classification, it is mainly the physical properties of the soil which will determine its agronomic and suitability class. The more important of these physical properties are those which influence directly or indirectly the water regime, water availability and water retention of the soils, functioning with and responding to the climatic conditions, especially precipitation. It should be realized that the environmental factors for the highest production of oil palm are those concerning climate. This is not to discount the importance of soil conditions in the cultivation of oil palm but the climatic conditions provide the main frames, as it were, from which the picture of the oil palm could be painted and hung.

Thus, there is increasing interest in and utilization of the soil moisture regime as function of climatic condition and soil physical characteristics in the assessment of the suitability of the areas for oil palm cultivation. This is then or should be followed by trials and experiments designed to evaluate the agronomic requirements of the oil palm in these areas or regions where the soils occur.

The soils in Malaysia and their distribution and properties will be discussed by Dr. Paramanathan, and the soils in which the oil palm is cultivated in Malaysia have been shown by Dr. Ng Siew Kee. To recapitulate, the main groups of soils on which the oil palm is cultivated in Malaysia are:

Tropaquept and Dystropept

Paleudult

Haplorthox and Acrothox

The other soils are of lesser importance. However, the Typic Sulfaquept, Typic Tropaquent and the Fibrists may become more important with the expansion of the soil palm cultivation to these soils in the near future.

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AGRONOMY OF SUGARCANE[1/]

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INTRODUCTION

Sugar yield is dependent on tonnage and piculs sugar per ton cane (PS/TC). Of these yield components, high tonnage yield is easier to achieve and tend to exert more influence in the final sugar production (Dosado et al., 1978, Dosado et al., 1980). For this reason, most of the cultural management practices in sugarcane production are directed in increasing tonnage. This paper discusses some basic principles and recent advances in Sugarcane Agronomy obtained through research.

CLIMATE

Sugarcane growing areas in the Philippines producing high sugar yields are characterized by evenly distributed rainfall and warm temperature for early growth and development. Cool and relatively dry period at least six-eight weeks before harvest enhance ripening and sucrose storage. The dry conditions at harvest is also necessary to facilitate entry of in-field transport, hauling of harvested canes and initial cultural operations using farm machineries.

SOILS

Well drained medium textured soils with a pH of 6.0 - 7.8 and high in organic matter and soil nutrients is desirable for sugarcane production. Soils with high productivity potential in terms of soil properties should be chosen for sugarcane production because this will require only minimum materials and management inputs to produce profitable yield (Rosario et al., 1985).

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Among these soils grown to sugarcane in Negros province are Isabela sandy loam, Umingan clay loam, Guimbalaon loam and Guimbalaon gravelly loam, with a productive potential values of 59.8, 59.7, 58.5 and 58.1, respectively, considered very good for sugarcane production (Table 1). These values were derived by multiplication of productive indices assigned to land slope, soil texture, moisture availability, pH organic matter content, available potassium and available magnesium (Hombrebueno 1980).

Based on records, highest sugar yields were consistently produced by sugarcane planters in Sulay, San Carlos, Bukidnon and Bais. In addition to good management practices of sugarcane planters, these areas are believed to have soils with productive potentials.

LAND PREPARATION

To have ease in field operation, newly harvested field trash in the wet season are turned upside down in order that these will dry thouroughly. The fire should be started against the wind direction to insure relatively satisfactory burning. Burning during the cool parts of the day is recommended to minimize loss of beneficial microorganisms.

When no burning is employed, the trash is incorporated into the soil by rotavators. This is followed by plowing to completely incorporate the chopped trashes into the soil. Moldboard plow maybe used to plow under the cane trash. Subsequent harrowing will incorporate the trashes into the soil.

Under Guimbalaon loam soils, one plowing at about 30-35 cm deep followed by two harrowings will make soil satisfactory for planting sugarcane. Additional plowing and harrowing will depend upon the judgement of the sugarcane planter.

For soils which has developed a hard-pan, subsoiling is employed without turning over the subsoil. Subsoiling is ideally done during the dry season condition to allow cracking of the subsoil.

Table 1. Index of potential production of soil types in Negros Occidental

SOIL TYPE	AREA	PRODUCTIVITY POTENTIAL	TOPOGRAPHY
1. Isabela sandy loam	1,163	59.8	flat
2. Umingan clay loam	1,313	59.7	flat
3. Guimbalaon loam	22,401	58.5	rolling
4. Guimbalaon gravelly loam	7,908	58.1	rolling
5. San Manuel loam	14,146	54.5	flat
6. Isabela clay	29,682	52.4	flat
7. Manapla loam	6,589	52.4	rolling
8. San Manuel fine sandy loam	2,218	50.8	flat
9. Silay fine sandy loam	32,435	41.8	flat
10. Bantay clay loam	55,826	41.1	rolling
11. Silay clay	11,089	40.0	flat
12. Louisiana clay	23,564	39.9	rolling
13. Silay loam	27,747	39.8	flat
14. La Castellana clay loam	18,142	38.5	rolling
15. Guimbalaon clay	71,366	38.7	rolling

CATEGORY	SUITABILITY INDEX	EQUIVALENT YIELD POTENTIAL PICUL SUGAR/HA
Very good	51-60	230-265
Good	41-50	185-230
Fair	31-40	140-185
Marginal	21-30	90-140

In medium textured and heavier soil types at the beginning of the season, the field may be too wet and it may not be feasible for tractors to make the land preparation. This is especially true when there is a desire to have a new plant crop after a number of ratoons. When the high yielding variety is susceptible to the disease and when ratooned crop will succumb to the pathogen, there is a necessity of having a new crop every year. These are some of the conditions which the "minimum tillage" practice could be of use. In brief, this "minimum tillage" practice is described as follows (Dosado, 1977):

A. WET SEASON

DAYS[1]		ACTIVITIES
1 DBP	1.	Burning of cane trash
0	2.	Planting between rows of cane using "tama" at 30,000-35,000 selected cane points per hectare
1 DAP	3.	Fertilizer application using "tama" more or less 180-90-120 or recommended rate of fertilizer for the area
3 DAP	4.	Pre-emergence application of 2 kg Karmex and 1 gallon 2,4-D per hectare
30-45 DAP	5.	Chopping at least two times the growing ratoons
56 DAP	6.	Breaker at 18-22 inches deep passes on old ratoons
57 DAP	7.	Irrigation to field capacity
45-70 DAP	8.	Spot weeding whenever necessary
70-90 DAP	9.	Breaker at 18-22 inches deep (Optional)
365 DAP	10.	Harvesting and milling

B. DRY SEASON

DAYS[1]		ACTIVITIES
2 DBP	1.	Burning of cane trash
1	2.	Breaker at 18-22 inches depth to uproot stubbles
0	3.	Planting using "tama" at 40,000 selected cane points per ha.
1 DAP	4.	Fertilizer application using "tama" at more or less 180-90-120 at recommended fertilizer rate for the area
2	5.	Irrigation to field capacity
3-4	6.	Pre-emergence application of 2 kg Karmex and 1 gallon 2,4-D per hectare
40 DAP	7.	Irrigation to field capacity (if necessary)
45-70 DAP	8.	Spot weeding whenever necessary
70 DAP	9.	Breaker at 18-22 inches depth)optional)
365 DAP	10.	Harvesting and milling

VARIETIES

The use of high yielding variety is the easiest and the cheapest way of increasing production. In as much as sugarcane varieties vary in their response to climatic and edaphic factors, the newly bred promising variety should show consistent superiority in yield for at least three seasons over the widely grown variety in the area before it is recommended for commercial production (Dosado, 1981). The recommended PHILSUCOM-bred sugarcane varieties is shown in Table 2 (Lapastora, 1981).

Tonnage is high towards the end of the rainy season and decreases with low precipitation while the opposite is true for piculs sugar per ton cane (PS/TC). For early milling at the end of the rainy season in October and November, the best age to harvest regardless of variety is 12 months. Varieties with high sucrose or PS/TC are recommended during this period. This include Phil 6723, Phil 56226 and Phil 6553.

Optimum sugar yields are produced for most varieties during the dry and cool mid-season harvest in December, January and February. High tonnage varieties like Phil 6607 and Phil 7495 harvested in 12 months and high sucrose varieties harvested in 10 months will produce satisfactory sugar production during this period (Dosado and Miayo, 1983; Dosado et al., 1985).

For late and dry milling season in March and April Phil 6723, Phil 56226 and Phil 6553 harvested in 10 months are recommended. Regardless of season, it appears that varieties with high sugar quality tended to produce more stable sugar yields. Phil 6553 has been found to be resistant to drought and has the least loss in weight among the seven varieties after 12 days of delayed milling (Miayo and Dosado, 1984). Variety with waxy rind are resistant to dessication.

Table 2. Characteristics of recommended PHILSUCOM-bred varieties

VARIETIES	YIELD POTENTIAL (PS/TC)	YIELD POTENTIAL (TC/HA)	OTHER CHARACTERISTICS	AGE AND SEASON AT HARVEST	DISEASE REACTION
Phil 56226	high (1.70 & Up)	high (100 & up)	Erect to recumbent self trashing moderate trichomes profuse flowering	Early milling - 12 months 10 months at harvest in December-April	Smut - very susceptible Leaf scorch - intermediate susceptible Downy mildew - susceptible
Phil 6553	high (1.70 & up)	high (100 & up)	Erect to recumbent self trashing no trichomes sparse flowering	Early milling - 12 months Mid-season harvest - 12 months Late milling - 10 months	Smut - resistant Leaf scorch - resistant Downy mildew - intermediate susceptible
Phil 6607	average (1.50-1.69)	high (100 & up)	Erect to recumbent self trashing no trichomes profuse flowering efficient in use of N, good ratooner	Early milling and midseason harvest - 12 months	Smut - intermediate susceptible Leaf Scorch - relatively resistant Downy mildew - very highly resistant
Phil 6723	high (1.70 & up	average (80 - 99)	Erect Semi-self trashing few trichomes sparse flowering good ratooner	Early milling - 12 months 10 months at harvest in December-April	Smut - highly resistant Leaf scorch - intermediate susceptible
Phil 7495	average (1.50-1.69)	high (100 & up)	Erect to recumbent self trashing no trichomes sparse flowering	Early milling and mid-season harvest - 12 months	Smut - resistant Downy mildew - resistant Leaf scorch - average yellow spot - average
Phil 7775	high (1.70 & up)	average (80-99)	Erect Self trashing sparse to moderate flowering	Early milling - 12 months 10 months at harvest in December to April	Smut - resistant downy mildew - resistant leaf scorch - average yellow spot - average

SEEDPIECE PREPARATION AND PLANTING

With the field ready for planting, seedpieces of the variety recommended for planting and harvesting in the area are prepared. The traditional seedpiece used have three viable buds taken from the top. The topmost part of the cane are not used as seedpieces because those germinate rapidly and produce weak shoots from the growing point. High germination percentage are obtained from 5-10 buds from the spindle. The buds must be free from insect damage. Before planting, the leaf sheath attached to the seedpiece should be removed to allow the set roots to immediately anchor itself into the soil.

For the conventional system of cane culture on soil with average fertility, furrows are laid out one meter apart and 30,000-40,000 selected three-eyed cane points from healthy plants are planted per hectare (Table 3) (Losado et al., 1978). This is about 3-4 cane points per linear meter. The higher rate of planting is recommended for the dry season. In the mechanized system of sugarcane culture, furrows are laid out at 1.5 meters and 40,000-50,000 selected cane points are planted per hectare. Cane points are planted flat during the dry season and slanting position during the rainy season.

To assure high germination, good quality seedpiece, adequate soil moisture, favorable soil temperature, absence of seed-rotting organisms and good land preparation are necessary. Good germination will result in perfect stand hence unnecessary expenditure in replanting and assured tonnage.

Result of the experiment at La Granja showed that 3 missing hills per 10 square meter (equivalent of 10% missing hills) will generally reduce yields than the need for immediate replanting (Tapay et al., 1981). Replanting should be made as early as possible. The use of chipped tillers for replanting in the ratoon crop is recommended when the soil moisture is favorable (Goteza, 1983). When newly cut canes are used in replanting in ratoons, they may be physiologically immature when the crop is harvested and canes with lower PS/TC are produced.

Table 3. Influence of hill spacing on sugar yields of four P[illegible] varieties

SPACING/PLANT POPULATION	VARIETIES[1/] Phil 6553 (1976)	Phil 56226 (1976)	Phil 56226 (1977)	Phil 6607 (1977)	Phil 6723 (1977)
30 cm (30,000 plts./ha)	182a	150a	165b	184a	164a
25 cm (40,000 plts./ha)	202a	174a	194a	216a	167a
20 cm (50,000 plts./ha)	207a	168a	173b	189a	171a

[1/] Means with similar within variety and spacings are not different at LSD .05

Better germination are obtained from cutbacks of about 6 months old or from three-eyed cane points from newly harvested cane top excluding the growing point. Study on Ja 60-5, a variety difficult to germinate show that beyond six months, there was an increase of pol, purity and brix which were attributed to low germination (Valdez, 1980). Application of 75 kg per hectare of nitrogen 30 days before cutback of 6-month old cane increased germination by 4-10 per cent (Harder and Lapastora, 1980).

To enchance germination and minimize adverse effect of seed-rotting organism, seedpiece may be treated with recommended fungicide, Benlate or Fungitox at 100 ga/200 liters of water (Jereza and Ampusta, 1978). It is better to treat seedpiece with fungicide immediately after cutting and not immediately before planting (Barredo, 1975). This is especially beneficial if planting is delayed beyond five days after seedpiece cutting.

Tillering starts from one month and peaks at 3-4 months after planting depending upon the variety and growing conditions. Adequate nutrition particularly nitrogen and phosphorus in combination with dry weather promotes tillering (Rosario, 1982). To encourage early flush of tillers which are likely to develop into millable stalks, two-thirds of the nitrogen per hectare should be applied during first of the split application (Garcia and Rosario, 1979). Application of at least two-thirds of nitrogen at planting produces more tillers and consequently higher sugar yield than the mechanical chipper cultivation (Table 4) (Gotera, 1984). Rapid growth development occurs 3-7 months. Adequate sunshine, moisture, nutrition and high temperature contribute to the formation of stalk materials. During this period inferior tillers dies and the population stabilizes.

Table 4. Plant characters and yield of Phil 56226 applied with chemical and mechanical treatments to enhance tiller formation.

TREATMENT	MEAN NUMBER OF TILLERS	MEAN NUMBER OF STALKS	PS/TC	TC/HA	PS/HA
1. Spraying Gramoxone	92,500	113,334	1.38	96	132
2. Chipper cultivation	91,667	117,223	1.47	112	164
3. Cutting primary tillers	88,334	110,556	1.42	86	123
4. 2/3 N at planting	146,112	131,389	1.44	124	182
5. Control	102,223	108,056	1.40	96	131

FERTILIZATION

Survey of soils in Binalbagan, Sagay, Dacongcogon and La Carlota, Negros Occidental reveal that nitrogen is most limiting in sugarcane soils in these mill district. Nitrogen is important in producing high tonnage and biomass (Santos and Rosario, 1983). Soils with high clay content seemed to be more responsive to nitrogen application (Zambello, et al., 1980).

Experiments with constant NPK ratio (1.0:0.5:3) but increasing NPK showed that 100-50-300 appears to be optimum for the plant and ratoon crops. In another experiment, ratio and rate of NPK was increased. As a whole, sugarcane responded to 100-200 kilogram nitrogen application in Guimbalaon sandy loam soils. No definite results were obtained by raising the levels of phosphorus and potassium (Espada, 1977). Research results from seven Phil varieties show that an average of 1.66 kg N, 0.39 kg P_2O_5, and 2.83 K_2O, 0.46 Ca, 0.56 Mg, 0.08 Fe, 0.008 Zn, 0.02 Mn and 0.007 Cu are required to produce a ton of cane (Gaston, et al., 1985).

For best yields and economy on the use of commercial fertilizer, the soil should be analyzed and the fertilizer recommendation based on the laboratory analysis should be closely followed (Quilloy, 1980).

The high cost of inorganic fertilizer has generated interest in the use of organic sources. The desirability of animal manure, farm waste and mill by-products as fertilizer has been reported (Cruz and Puyaon, 1971; Tianco, 1983; Urgel and Macalintal, 1984). Many sugarcane planter are now incorporating cane trashes into the soil instead of burning them. Among the most readily available organic sources as soil ameliorant is filter cake or mudpress. An application of 20 tons of mudpress per hectare and its residual effect of the ratoons has shown increase in cane and sugar yield over the mudpress treatment (Table 5) (Urgel and Hernandez, 1971). Dried ipil-ipil leaves at five tons per hectare has also shown promise (Gerardino and

Hombrebueno, 1984). The fertilizing value of decomposed mudpress AND bagasse has also been reported (Navarro and Gimotao, 1981).

To reduce the amount of mudpress to be used, the ratio of its amount when combined with inorganic fertilizer has been studied. Mudpress-Urea fertilizer combination at 1:1 or 1:2 has been found to produce cane and sugar yield comparable to that of Urea alone (Quilloy, 1983). The fertilizing value of mudpress and bagasse is shown in Table 6 (Cruz and Puyaon, 1971). Earthworm castings of one ton plus 126 kg nitrogen and 64 kg P_2O_5 commercial fertilizer was also found to have similar yield compared with 140 kg N + 70 P_2O_5 (Quilloy, 1985).

During the dry season, the recommended fertilizers are all applied as basal application. In the wet season, however, one half to two-thirds of nitrogen and potassium and all of phosphorus one month after planting and the remaining amount 3-4 months later before the las cultivation or hilling-up.

CULTIVATION AND WEED CONTROL

To improve aeration and control weeds, cultivation is made with a carabao-drawn plow or tractor drawn cultivator. The first cultivation or "ridge busting" is done about 3-4 weeks after planting by passing the plow between the furrows with the soil thrown towards some exposed cane points and to cover up the recently applied inorganic fertilizer. Off-barring may be done 7 weeks after planting. Subsequent cultivations are alternate hilling-up and off-barring depending upon the weed population. Weeds between hills are removed manually. The final hilling-up is done to cover the second dose of fertilizer. Hilling-up keeps the stalk upright, suppress the late tillers, and serves as drainage for excess water and cover the weeds growing in between the furrows.

The time of the last cultivation or hilling-up differs among varieties and seemed related to the leaf canopy formation. Phil 6607 and Phil 56226 which forms leaf canopies in two and a half months and four months, respectively, produce best yields when hilled-up during these periods (Miayo and Dosado, 1982).

The critical period of weed control is three-four months after planting (Cruz, 1978).

Table 5. Mean cane and sugar yields of plant and ratoon crops as affected by different rates of mudpress application.

CROP	CRITERIA	TONS MUDPRESS PER HECTARE				
		0	10	20	40	80
Plant cane	TC/Ha	90.85	96.57	96.86	88.38	80.28
	PS/TC	1.76	1.72	1.65	1.61	1.46
	PS/Ha	152.52	166.87	160.44	143.66	117.61
Ratoon cane	TC/Ha	74.49	73.13	85.11	84.11	85.94
	PS/TC	1.78	1.73	1.71	1.76	1.72
	PS/Ha	132.99	127.18	145.55	148.55	147.79

Table 6. Fertilizer value (kilograms) of 10 tons of bagasse and mudpress

	N	P	K	Ca	Mg	Fe	Cu	Zn	Mn
Bagasse	37	2	5	1.3	1.2	4.4	0.09	0.09	0.17
Mudpress	20	46	20	77	11	80	80	0.83	294

Table 7. The influence of the duration of weed control in sugarcane

DURATION OF WEED CONTROL FROM PLANTING	PS/HA	% INCREASE
No weed control	103	
1 month	144	40
2 months	151	47
3 months	161	56
4 months	159	54

In large sugarcane planta tion, the use of herbicides is resorted to especially when labor for weeding is scarce and the soil is too wet foi mechanical and manual weeding due to frequent rainfall.

Weeds are susceptible to the herbicides at the 2-3 leaf stage. The herbicides should be applied in the early morning of a sunny day. The herbicides can effectively control weeds four hours after it has been applied. In frequently raining areas, the "sticker" may be added to the herbicide to minimize its loss.

In pre-emergence application, the soil should be thoroughly prepared so that the herbicide may be able to move in the wet soil and inhibit germination of weed seeds. To economize in the use of herbicides, early post (2-3 weeks after planting) of Karmex (1.5-2 kg/ha) plus 2.4-D Amine (1 gal per ha) will suffice to kill young grasses, sedges and broadleave weeds.

In fields where weeds are mostly Cleome or Cyperus, the most economical with high return among weeding methods is blanketing post emergence spray of 2,4-D (1 gal/ha) combined with two handweeding (2x) along the rows and plow cultivation between furrows (Cruz, 1978).

One weeding in six weeks will give comparable yields in places where weed species are mostly Portulaca or Cyperus. This may be different in grass infected areas (Punzalan and dela Cruz, 1980).

Another cheaper way to control weeds is to plant a fast growing variety like Phil 6607 whose leaf canopy closses-in two and a half months. With this variety less number of cultivation is needed. Phil 6607 was also observed to tolerate weeds between rows which will eventually die due to shading. Only weeds between hills and those close to the cane plant should be removed (Cruz, 1983).

PESTS AND DISEASES

[illegible] ito the newly bred hybrids has made substantial success in controlling sugarcane diseases. In the breeding program of the Philippine Sugar Commission, the newly-bred variety is recommended for commercial production only after it has shown satisfactory resistance to smut, downy mildew and leaf scorch - major sugarcane diseases in the Philippines today. The severity and the economic importance of yellow spot and rust diseases are being evaluated whether they should be included in the screening program.

In as much as the different varieties differ in their degree of resistance to a particular disease, two or more varieties of sugarcane should be grown in the farm to minimize loss in case of disease epiphyto

On account of its high cost, the use of fungicides is limited to treatment of seedpieces previously discussed under "Seedpiece Preparation and Planting".

For pests, sugarcane borers is the most serious. Application of five strips of Trichogramma sp (3000 parasite per strip) with emerged eggs per hectare 4-5 times at weekly intervals lowers borers infestation. Average parasitization on borer eggs of 70.35% per hectare has been reported (Alba, 1981).

Infestation of armyworms and locust sometimes occur at certain year. Blanket (total area) spraying of contact insecticide is recommended. Cleaning the surrounding fields may discourage the multiplication of these pests.

In many soils, parasitic nematodes have been observed and may reduce sugar yields under certain population threshold. Incorporation of molasses, mudpress or filter cake, composted sugarcane bagasse all applied at 30 tons per hectare can control nematode population. Chicken manure has nematode trapping fungi which also affect nematode population Band application at planting time of Temik at 3 kg a.i./ha; Furadan 3G, 2 kg. ha; Nemagon, 6.6 kg/ha; Hostathion, 2 kg/ha and Basudin 5G, 3 k ha suppress nematode population and increase cane and sugar yield (Reyes and Deguico, 1977).

Rodents have been observed to cause varying intensity of damage from year to year. They showed preference for soft rind and sweet varieties of sugarcane. The incorporation of anti-coagulant (Ratoxin, Racumin, Tomorin, etc.) in bait materials such as corn grits, roasted grated coconut and broken rice have been effective in controlling rat (Estioko, 1981).

IRRIGATION AND DRAINAGE

In some sugarcane areas, there is a distinct wet and dry season. The newly planted cane points in the dry season may need irrigation to initiate germination and early growth and development of the young seedlings. Rapid stalk elongation starts 3-4 months with maximum rate at 7 months. Since this growth period is important in tonnage, production stress such as moistures should be avoided. Four to seven irrigation during this period will give substantial production.

In San Carlos, a mill district with low annual rainfall, about 19 piculs were produced by irrigation over rainfed sugarcane plantation. The benefit/cost ratio was 2.5: (Caintic, 1971).

The field should be irrigated to field capacity the frequency of which will depend on the weather conditions and soil types. Irrigation water should be witheld about six-seven weeks before harvest

Standing water in the field especially in flat areas should be drained. This is deleterious to the growth and development of the growing canes. Small canals are generally made in the field to drain standing water.

HARVESTING AND CULTURE OF RATOONS

Harvesting is one of the critical operations in sugarcane farming. The gain or loss in capital invested in all operations preceeding harvesting depends primarily on the time of harvesting. To get the highest possible sugar from the cane, the crop should be harvested at maturity (Dosado, 1981).

Cane maturity in a given set of conditions is determined by cane variety, cultural practices, (nitrogen fertilization, moisture control and ripener application) and climatic conditions (rainfall).

Maturity and Variety

Sugarcane varieties differ in their physiological maturity due to their varying photosynthetic efficiency and genetic characteristics. The age and season at harvest is thoroughly discussed under "Varieties".

Maturity and Fertilization

Late application of nitrogen will enhance vegetative growth thus delaying sucrose storage, flowering and maturity.

Maturity and Moisture

In luxuriantly growing cane, the moisture content of immature internodes is high. To hasten the physiological maturity of the cane, the moisture content should be reduced, especially when the canes have attained the age of about twel months. Rainfall occurring when the cane is ready for harves is undesirable because it lowers the brix and corresponding decrease in sugar. Delayed harvesting after a heavy rain co cause inversion of sucrose and initiate re-growth which will eventually reduce the weight of the stalk.

Use of Ripeners

The application of chemical ripeners 6-8 weeks before harvest during the rainy season, when polarization is low increases sugar quality (PS/TC). Polaris (5 kg a.i./ha), Embark (1.12 kg a.i./ha) and Glyphosate (0.3 kg a.i. Mon 2129) were found effective in increasing piculs sugar per ton cane. The ripener tended to stop growth and enhance sugar storage.

Experimental results in Negros Occidental and Iloilo have shown an average increase in sugar quality of about 20 per cent for Polaris, 24 per cent for Embark and 26 per cent for Glyphosate.

Delay in harvesting of ripener-applied cane field however, may adversely affect sugar content.

Maturity Determination

The dominant influence of climatic and cultural factors makes chronological age of the variety and unreliable index of maturity. When these factors prevail, it is necessary to base harvest time on some structural and physiological changes in the plant. With regards to these changes, 12-14 green leaves and long internodes in the terminal portion indicate continued vegetative growth. These long internodes in the terminal portion are filled with moisture and reducing sugar. The sugar produced in the leaves are not being stored as recoverable sucrose but is used as energy for continued vegetative growth. When these characteristics are observed, harvesting should be done when the desired maturity has been attained.

The following are guides in ascertaining cane maturity:

1. Brix reading by use of hand refractometer. Maturity is indicated by a more or less uniform brix reading of the juice collected from the top, middle and basal portion of the stalk. An immature stalk has high brix at the base and low at the middle and the top. The over-mature register high brix at the top and low at the bottom.

2. Visual observation. A cane field ready for harvest exhibit these characteristics:

a. Yellowing of the leaves in the whole plant is uniform

b. The stalks becomes yellowish

c. Internodes in the upper portion shorten

Harvesting Practices

There are two methods of harvesting sugarcane, by manual operation and by machine.

Sugarcane in the Philippines is harvested manually by cane knife or "machete". The base of the stalk is cut close to the ground and the terminal portion is separated or removed before the stalks are piled or loaded. Cutting the base as close as possible to the ground is important because it facilitate stubble shaving in the subsequent ratoon. Also, sugar present in the base is recovered and not wasted. The terminal portions or cane tops removed from the millable stalks are used as seedpieces for planting. The seedpieces with three buds each are usually obtained from the terminal portion.

The cane cutters should separate the trash (dried leaves, tops, dried stalks) from the stalks. When the trash is mixed with the cane during milling, sugar recovery is adversely affected. The trash absorbs sugar and imparts impurities into the juice during milling.

Cut canes should be hauled immediately to the factory. Sugar content and tonnage decreases when milling is delayed. Loss of about 3.08 tons and 0.013 per hectare per day for tonnage and PS/TC has been reported (Mercado et al., 1977).

Large farms resort to mechanical harvesting to enable them to harvest all their cane fields before the close of the milling season. These farms usually do not have enought labor force to do the harvesting.

Before going from traditional to mechanical harvesting, a thorough study of many aspects of the system should be made. In mechanical harvesting, it is necessary that the field should be relatively level, well-drained, free from stones, tree stumps, anthills and extrenous materials which may damage the base cutter of the harv ter. The soil should be of lighter type, and grown preferably with a non-lodging and self-trashing variety. The furrows should be laid 1.5 meters apart, long enough for efficient operation and provided with unplanted area at the end of the field to enable the harvester and the back-up transport to turn around.

To be able to cut close to the base of the stalk, the rows of the canes to be harvested should be slightly elevated to minimize soil intake. This may be done by hilling-up durin the last cultivation.

In harvesting, the blade of the harvester passes at the base of the stalk; at the same time the upper blades cut the top. The cut stalk is elevated by a roller and chopped into short pieces over a foot long and dropped into a trailer or truck following the harvester. Some lighter trash are carried away by the blower. The machine could harvest about 29 to 36 tons per hour.

On account of more surface area for moisture evaporation and dessication which caise tonnage loss, and to minimize souring due to Leoconostoc organism, the newly harvested canes should be milled within sixteen hours.

Practices To Avoid In Harvesting

1. Burning of Canes Before Harvesting. Except in avoid circumstances or special cases, canes should not be burned befo harvesting. The death of the cells of the stalk as a result of burning caused the inversion of the sucrose content of the cane reducing sugar - a form which cannot be crystallized.

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In case burning cannot be avoided, burnt canes should be harvested immediately and milled within the shortest time possible. Burnt cane left uncut or standing in the field will continue absorbing water from the soil which cannot be lost rapidly by transpiration because of the destroyed leaves.

2. Delayed Harvesting After Topping - Topping is the removal of the terminal portion of the stalk of the standing canes to secure seedpieces for planting. Delayed harvesting or long interval between topping and harvesting also results in sugar losses.

3. Milling of Trashy Canes. Milling canes with trash affects sugar recovery and imparts impurities in the juice. To minimize this, some sugar mills are giving incentive allowance for delivering clean canes to the mill.

ESTIMATING SUGARCANE TONNAGE BEFORE HARVEST

An estimate of tonnage before harvest is a valuable guide in the programming of budget, labor and equipment. For farm managers, it could be the basis for estimating the number of workers needed for harvesting and the number of trucks that could accommodate the hauling of these canes.

A formula in estimating sugarcane tonnage is as follows (Hombrebueno, 1981):

Estimated tonnage = P (100-CF) where:

P - the average number of millable stalks per square meter X the average weight of stalk x 10,000 square meters per hectare divided by 1000 kilograms per ton.

CF - (Correction Factor) the expected losses expressed in percentage due to factors that may affect tonnage at the time the estimate was made. Yield constraints brought about by pests and improper cultural practices are already manifested in the weight of stalk and should not be taken into account in this computation.

As an example, the following given:

a. Average number of millable stalk per square meter = 12

b. Average weight of stalk (Phil 56226) = 1.02 kg

c. Correction factors

Rat damage = 8%

Missing hills = 11%

Lodging canes = 3%

$$\text{Estimated tonnage} = \frac{12m^2 \times 1.02\ kg \times 10{,}000\ (100-22)}{1000}$$

$$122.40\ (78\%) = 95.47\ tons/ha$$

CULTURAL PRACTICES FOR RATOON

In view of the high cost of inputs and fossil fuel, the cultu of ratoon has generated interest among the sugarcane planters. Ratooning reduces cost of production by eliminating land preparation and cost of canepoints used in planting a new crop. Practices generally adapted for a successful ratoon crop production are as follows:

Choice of the Variety. Varieties differ in their persistence in producing high ratoon yields. Varieties that are susceptible to systemic diseases that are likely to be carried to the ratoon crop are not desirable for use in the ratoon. Varieties which produced high tonnage in the plant crop and have good germination in the ratoo crop are recommended for ratooning (Dosado *et al.*, 1977). In recent studies at the La Granja Sugarcane Experiment Station, satisfactory yields were produced when Phil 56226 and Phil 6607 were ratooned twice and Phil 6723 three times. These data were obtained in plots without replanting (Miayo and Dosado, 1985).

Trash Disposal. Before growing a ratoon crop, the trash of the previous crop is disposed off by burning or trash mulching. Burning i the easiest and cheapest way of disposing trash. In the process, it destroys sources of pests and diseases found in the trash. However, the organic matter in the soil is destroyed. Trash mulching is the piling of the trash in alternate rows or applying them as blanket cove This practice conserves soil moisture, reduce surface run-off of and minimize soil erosion during heavy rains. Despite of these advantages, the practice is not widely done because of high labor cost in preparing the field. And in areas where drainage is poor, the trash interfers with the disposal of excess water and impedes evaporation.

Stubble Shaving. After canes are harvested, there remains under the ridge a portion of the stool or stubble where new crop emerges as ratoon. For a vigorous ratoon crop, the exposed portion of the stubble or even part of the underground portion is cut or removed. This is known as stubble shaving. The stubbles are shaved soon after burning of the trash or after trash mulching. Delay in stubble shaving have been reported to reduce sugar yield. In the absence of a stubble shaver, a sharp "machete" can be used for stubble shaving.

Cultivation, Weeding and Fertilization. After stubble shaving, the soil is plowed away from the base of the stubble into the interspace between the rows. This operation cuts off most of the old roots, allows aeration of the soil and induces the formation of the new roots.

Immediately after the off-barring, the fertilizer in the amount similar or a little more than the plant crop fertilizer recommendation are applied along the rows and covered with soil. Replanting of missing hills with chipped tillers from neighboring hills with large number of tillers are made when moisture conditions is favorable. If cane points are used, they should be planted in the missing hills with the use of "tama" or pointed iron immediately after the stubble shaving or as soon as the missing hill is identified so that it will mature at the same time with the ratoon.

Subsequent cultural operations will be hilling-up and off-barring and weeding depending upon the prevalence of weeds with the final hilling-up before the cane leaves canopy closes-in.

<u>Harvesting</u>. Ratoons generally attain physiological maturity faster and should be harvested earlier than the plant crop.

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AGRONOMY FOR CASSAVA[1/]

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INTRODUCTION

Cassava (Manihot esculenta Crantz) ranks eight as a carbohydrate source in terms of hectarage after rice, maize, barley, sorghum, millet, potatoes and rye (FAO?,1984). Of the 14.9 million hectares devoted to cassava, about 54% is in Africa, 27% in Asia and 17% in South America. Table 1 shows the area, production and average yield of cassava in some Asian countries. Thailand, Indonesia and Vietnam are the three biggest producers of cassava.

Cassava is largely used as human food (about 65%, animal feed (18%) and industrial use and starch (5.5%)(Cock, 1985a). It is one of the most efficient starch procedures. Cassava roots contain 20 to 40% dry matter about 85% of which is starch.

Cassava has no great advantage over other crops under optimum growing conditions but its yield potential exceeds those of other crops under suboptimal conditions. This is probably the reason why cassava is mostly grown under marginal conditions.

In Asia in general (with the exception of Thailand) cassava is produced by marginal subsistence farmers. A few areas devoted to the commercial production are more of the exception rather than the rule. Thus, the emphasis of this paper is more on the low-input technologies which are more applicable and appropriate for use by small cassava farmers.

1/ Paper presented at the XIV International Forum on Soil Taxonomy and Agrotechnology Transfer for the ASEAN region, held in the Philippines.

ADAPTATION

Cassava is adapted to diverse agroclimatic conditions but naturally yield is affected when not grown under favorable conditions. It grows best at temperatures ranging from 25°C to 29°C. In the tropics, this is not much of a problem except in high altitude areas where temperature is low. At temperatures of 10°C and below growth and development is inhibited.

In areas where rainfall is uncertain and where long dry periods are experienced, cassava is a low risk crop to plant. However, it does best in areas where rain of 100 to 150 cm is well distributed throughout the year.

Daylength and solar radiation affect the growth and yield of cassava. Short-day conditions promote storage root initiation. Long days promote stem growth and reduce storage root yield due to the limitation of assimilate supply to the roots. Twelve hours daylength is reported to be optimum for cassava. In the tropics where daylength varies minimally, light duration may not be an important factor in determining yield. Light intensity however greatly affects yield. Whyte (1985) reported that 60% shading cause a 36% yield reduction. Results of the National Cooperative Trials in Cassava in the Philippines (unpublished data) show that yield is reduced by about 50% under coconut where light penetration is also about 50%. There are however varietal differences and therefore the chance of finding a tolerant variety is great. At PRCRTC we are currently working on screening for shade tolerance since there are many coconut areas where cassava is grown.

Waterlogging is detrimental to the crop. Standing water of even just a few days can wipe out the whole crop due to the rotting of the roots. Thus, cassava should be grown in permeable soils. Other soil characteristics favorable for growing cassava are shown in Table 2.

Since most of the good soils are reserved for the more high valued crops, cassava has to be grown under more marginal conditions where it has a comparative advantage over other crops. To get a good yield however, it is necessary that light and drainage conditions be favorable.

CULTURAL MANAGEMENT

Land Preparation

Like any other corp, cassava needs a well-prepared land to insure good establishment and to minimize weed competition especially during the early stages of growth. In general, one plowing and harrowing is adequate for areas just previously planted. Depending on soil tilth and weed incidence, two to three plowings and harrowings maybe necessary for newly-opened or fallowed areas.

Land preparation practices are influenced by climate, soil type, vegetation, topography, degree of mechanization and other agronomic practices. In new forest clearing, no land preparation is required except cutting down of vegetation and burning before planting is done In areas where mechanization is available, land is plowed and harrowed/disked with animal or tractor power. In areas subject to waterlogging, ridges or mounds are constructed to prevent rotting of cassava roots and death of the plants.

Depth of plowing may affect root yield especially for heavier soils. In lighter soils, depth of plowing from 10 to 20 cm did not significantly affect yield (Toro and Atlee, 1980). Villamayor (1983) also found no advantage in preparing the soils deeper than 20 cm.

Variety Selection

Although cassava as a crop has wide adaptability, its it is necessary to plant varieties that are most suitable in a particular area. Regional trials provide the necessary information on the suitability of a given variety to a particular set of environmental conditions.

A good cassava cultivar is characterized by high yield, resistance to pests particularly the mites, high starch content, early harvest, low hydrocyanic content and good eating quality. Present recommended varieties in the Philippines have yield potential of about 40t/ha under experiment stations even without fertilization.

The use of modern or new cultivars are shown to be better than the traditional ones even under the system of management of the farmers (Table 3).

For those who are interested in selecting an ideal variety to be used under good growing conditions, Cock (1985b) listed the following characteristics: late branching at 6 and 9 months after planting; without suckers or side branches; large leaf size (ca. 500 cm^2/leaf) at 4 months after planting; leaf longevity of about 100 days; harvest index greater than 50%; leaf area index between 2.5 and 3.5 for most of the growing cycle nine or more roots per plant when planted at 10,000 plants/ha; and each plant with two main shoots from the original cutting.

Selection and Preparation of Planting Materials

The use of good quality planting materials is a very low input technology that is easy to adopt. To insure good yield only cuttings that are free from insect pests and diseases, mature, fresh and selected from vigorously growing plants should be used. Tables 4, 5, 6 and 7 show how the quality in terms of nutrition, insect pest, vigor, and freshness of the cuttings affect the yield performance, respectively.

The length of the stem cuttings varies from 20 to 30 cm depending on the number of nodes. There should be at least 5 nodes per cutting to have a better chance of sprouting and survival. Cuttings which are too long (ca 50 cm or more) or too short (10 cm) do not perform as well as the 25 cm cuttings (Tables 8 and 9).

Stems to be used as planting materials should be at least 6 months old. The best part of the stem to use is the middle part, the terminal part being too young (dry easily) and the basal part too old (lignified with little reserve food). A guide to the maturity of the stem as a planting material is t size of the pith (central soft portion) relative to the total cross section of the stem. The pith's diameter should be 50% or less than the total diameter.

Stems which are too thin should not be used. As a guide, the thickness of the stem should not be less than half t regular size of the variety. When the stems are thin not becau of poor growing conditions but because of cultural practices su as in high density planting the stems may be thin but their performance is not affected (Table 10).

If stored stems have to be used, the stems should be properly stored to maintain its viability and yielding ability. Table 11 showed that a properly stored cutting can still be used as planting materials. In using stored stems, only those with enough moisture content should be used. A stem has sufficient moisture if upon cutting, the latex appears within three seconds. The germinated and rooted parts should be discarded.

Before storage, dipping the long selected stems in a fungicide-insecticide mixture (Table 12) is recommended to prevent insect and disease attack. The stems are bundled

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positioned vertically with buds facing up on top of the soil in a well-ventilated area with relative humidity of 80-90% and protected from direct sunlight.

Planting

In places where rainfall is distributed uniformly, cassava can be planted anytime. In the presence of a dry period it is usually best to plant at the onset of the rainy season (Table 13) since yield is reduced when planting is delayed towards the dry season.

When the growing conditions are favorable, the position of planting is immaterial. However, when rainfall is uncertain it is best to plant horizontally in the furrow while in the presence of too much rain it is better to plant vertically on ridges to prevent the drying and rotting of the cuttings, respectively. Only one cutting per hill is planted. Depth of vertical planting from 5 to 15 cm does not affect yield (Table 14). When the cuttings are planted diagonally, horizontally, in inverted position or vertically but the whole stem is buried, there are underground shoots that arise. When this happens, the underground stems become storage organs and these are not attractive in the market. The quality of these storage organs is also not known.

The planting density/spacing seems not to affect the yield from 7,000 to 28,000 plants per hectare (Tables 15 and 16). There is a trend however, that the marketable yield decreased with increasing plant density (Table 16). When the density is too high (Table 17), root yield is decreased but stem yield is increased. Thus, the high population density planting is a good strategy for massive cutting production.

When the soil is not fertile and the variety is not branchy, the population density should be higher, about 20,000 plants per hectare. On the other hand, in fertile soil and with vigorously branching varieties, the lower population density should be used, about 10,000 plants per hectare.

When missing hills occur, it is not necessary to repla if it is less than 30% and randomly distributed (Villamayor a Labayan, 1984). If replanting is to be done, it should not b more than two weeks after planting to be effective.

Weed Control and Cultivation

Cassava is very susceptible to weed competition during the early stage of development when the canopy is not yet closed. This period usually lasts for 2-4 months depending on the growing conditions Under experiment station where the soil is not so poor, the critical period of weed control is about two months (Table 18). This means that the weeds should be controlled within this period to get the maximum benefit.

Weeds are usually controlled manually (handweeding) when labor is not a problem. Oftentimes however, labor is scarce and farmers usually control weeds through cultivation (off-barring and hilling-up) with minimum handweeding (Table : Cultivation, aside from controlling weeds also loosen the soi which is beneficial for the developing storage roots. When la is really very scarce, farmers plant cassava in a square mann so they can cultivate in perpendicular directions.

There are other ways of controlling weeds. One is to use higher population density to lessen the time from plantin to canopy closure. Another method is to intercrop with short maturing crops which cover the ground when the cassava plant i still small to compete well with the weeds.

For cassava plantations where labor is expensive, mechanical cultivarors are also used to control the weeds.

Herbicides can also be used effectively and economically. A mixture of diuron and alachlor applied before cassava emerges is found to e effective while a new premergence mixture, oxifluorfen mixed with alachlor may eliminate the need for any handweeding (Cock, 1985b).

Irrigation

Although cassava is a drought tolerant crop, its yield is also reduced when rainfall is limited (Table 20). Cassava is especially susceptible to moisture stress during the first two months of growth when the roots are still developing rapidly. A two-month period of water stress from one to three months and from 3-5 months after planting reduced the cassava yield by about 60% while at 5-7, 7-9, and 9-11 months, the yield is reduced by only about 10%. Since cassava is a low-valued crop, irrigation might not be economical. Thus, the best way to prevent water stress is to plant at the onset of the rainy season.

Fertilization

Since most cassava areas are marginal it is expected that it will respond to fertilization. Table 21 shows dramatically the effect of fertilization in farmers field. In fact, the income was highest under full fertilization (Villamayor, unpublished data).

In more fertile areas, cassava does not show any response at the beginning. At the PCRTC experimental field which was fornerly planted to rice cassava gives a yield of 30-40 t/ha in 10 months for about five years without fertilization. Presently, cassava yield is only half that much without fertilization although there was no response to fertilization initially. Cassava is so efficient in extracting nutrients from the soil that yield declines without fertilization under continuous cropping (Table 22). This is probably the reason why cassava is known as a nutrient depleting crop. However, comparing cassava with other crops, it does not extract more nutrients than potatoes, beans, maize or rice except perhaps for potassium in the case of maize and rice (Table 23).

Usually, cassava occupies the last crop in a cropping sequence before fallowing. This is probably one reason why cassava is labelled as a nutrient depleting crop. If nutrient depletion will be based on the total yield, it is true that cassava extracts a large amount of nutrient but that kind of comparison is unfair. A fairer basis of comparison is the amount of nutrient removed per ton of dry matter produced as shown in Table 23.

Most farmers do not apply fertilizer to cassava because of economic constraints For these farmers it is better to recommend crop rotation especially with legumes or fallowing to minimize nutrient depletion and imbalance. The use of organic fertilizer is also recommended whenever practical and economical.

For farmers who can afford to fertilize, fertilization is recommended to maintain the soil productivity. Since the recommended amount depends on agroclimatic conditions, a fertilizer trial has to be conducted to determine the economical levels. Tables 24 and 25 provide a guide when the probably how much to fertilize.

Pest Control

In the Philippines, one of the reasons mentioned by farmers for planting cassava is its resistance to pests. In reality, there are many pests affecting cassava. Fortunately, in most Asian countries only a few are serious.

Two species of spider mites, Tetranychus telarius L. and T. kansawai Kishida, are considered serious pests especially during the dry season. They suck the plant sap from the undersurface of the leaves and the infested leaves gradually turn from yellow to brown before falling off. Yield loss is high when severe infestation occurs during storage root formation and early bulking state (2-4 months after planting). Recommended control measures are stripping and burning of affected leaves, use of clean cuttings and resistant varieties, and timing of planting such that the critical stage of growth does not coincide with the peak of mite population. The use of resistant varieties and biological control measures are still to be developed under Asian conditions.

Another pest which is becoming serious especially under continuous cassava cultivation are the scale insects (still unidentified in the Philippines). They suck the sap from the stems which make them unfit for planting due to reduced sprouting ability. The use of resistant varieties and clean planting materials are recommended control measures. Several varieties are observed to be resistant to the insect. The insect can also be controlled chemically but since chemical are rarely used by farmers the potential of botanical insecticid as a control measure should be explored.

Among the cassava diseases, the cassava bacterial blight (Xanthomonas manihotis) (Arthaud-Berthet) Starr is the most serious and destructive especially during the wet season. Symptoms of the disease are angular leaf spotting and blight, wilting, die-back, gum exudation and stem and root vascular necrosis (Lozano et al., 1981). Total yield loss occurs when infection is severe. The use of resistant varieties coupled with cultural practices like wider spacing, elimination of infected plants and use of bacterial-free planting materials are the most promising control measures.

Harvesting

For subsistence farmers, the age of harvest does not matter much as long as they get sizeable roots to eat. For those who grow the crop for business, the crop should be harvested at the right time to get the maximum benefit. If harvested early, yields will be low and if harvested late, the starch and dry matter content may be low. In addition, starch content declines markedly at the onset of the rains following a dry season.

The right age of harvest also depends on the variety. Table 26 shows 18 months to be the optimum harvest age if the only consideration is the root weight. However, the quality of the roots also affect the decision when to harvest. To determine the best time to harvest, pull out a few sample plants randomly in the field and evaluate the eating quality. If there is no more increase in yield and the quality is alright, the crop may be harvested.

For the fresh market, only the needed amount should be harvested at any one time since the roots deteriorate very fast within two to three days after harvesting. In this case stagger harvesting from one end of the field to the other end should be practiced so that the harvested area can be immediately used for other crops if desired.

At harvest, the tops are usually cut leaving a stump about 30 cm long for grasping during uprooting of the plant. If the soil is hard harvesting aids that grasps the stem as it is raised make the operation less difficult.

If cassava is to be processed into chips, harvesting has to be done during the dry season since artificial drying is expensive and uneconomical.

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Table 1. Area, Production and Average Yield of Cassava in some Asian Countries.

COUNTRIES	AREA (103)	PRODUCTION (103 MT)	YIELD (MT/ha)
Indonesia	1,400	13,770	9.84
Malaysia	35	375	10.71
Philippines	210	2,300	10.95
Sri Lanka	62	570	9.19
Thailand	1,300	17,000	13.08
Vietnam	485	2,700	5.57

Source: FAO, 1984.

Table 2. Soil characteristics for cassava production.

CHARACTERISTICS	OPTIMUM RANGE	MARGINAL RANGE
Slope	0-8%	8-15%
Soil drainage	Well-drained	Moderately well-drained to excessively drained
Soil texture class	Silt loam to clay loam	Sandy loam to kaolinitic clays
Inherent fertility level	-	Low
Salinity	0-2 mmho/cm	2-4 mmho/cm
pH	5.2-7.0	4.5-8.2
Calcium carbonate content	0-1%	1-10%

Source: PCARRD Technical Bulletin No. 19-A

Table 3. Yield of a traditional and a new variety in trials managed by farmers with different skills and under different technology.

TYPE OF TECHNOLOGY AND VARIETY	TYPE OF FARMER GOOD	POOR
	Yield (t/ha)	
Traditional		
Secundina (old)	10.0	6.1
CM 342-170 (new)	20.5	9.6
Improved but no fertilizer		
Secundina (old)	16.5	10.5
CM 342-170 (new)	21.4	19.7

Source: Cock, 1985c

Table 4. Effect of Fertilization of Mother plants used for Stem Cuttings on Yield of Daughter Plants

FERTILIZER TREATMENT (kg/ha) N	P	K	FRESH ROOT YIELD AND DAUGHTER PLANTS (T/ha)
0	0	0	19.1
100	0	0	26.4
0	87	0	29.2
0	0	125	23.7
100	87	125	26.2

Source: CIAT (1981)

Table 5. Sprouting 14 days after planting and total root yield at 7 months after planting of scale insect-infested cassava (cv. Golden Yellow) cuttings soaked in insecticide solution before planting.1/

KIND OF CUTTING	SPROUTING (%)	ROOT YIELD (kg/4.5 m^2)
Healthy (no visible scale-insect	100.0a	5.9a
Scale insect-infested (soaked in insecticide solution)	35.0b	5.8a
Scale insect-infested (unsoaked)	25.0c	3.8b

1/ Within columns, means followed by a common letter are not significantly different (LSD, 5%).

SOURCE: Villamayor and Perez, 1985

Table 6. Effect of positive mother plant selection on yield of daughter plants (t/ha)

MOTHER PLANTS	MEDIA LUNA	CARIMAGUA	CIAT
High yielders	24	12	16
Low yielders	18	9	11

SOURCE: CIAT, 1982

Table 7. Sprouting and yield of cassava (cv. Golden Yellow) under different storage method and duration.[1/]

TREATMENTS	STORAGE DURATION (MONTHS) SPROUTING (%)	YIELD (%)	SPROUTING (%)	YIELD (%)	SPROUTING (%)	YIELD (%)
Position of storage						
Horitontal	96.0	93.0	99.1	73.0	96.3	53.2
Vertical	99.1	91.3	100.0	60.3	90.7	51.2
Inverted	100.0	102.7	100.0	63.1	91.7	51.8
Location of storage						
Shade	98.1	95.1	100.0	68.9	98.8	59.3
Open	98.1	96.3	99.4	62.0	97.0	53.6

1/ Sprouting and yield are expressed as percent of control (fresh cuttings)

SOURCE: Villamayor and Perez, 1983

Table 8. Root yield, number of branches and harvest index of cassava (cv. Golden Yellow) as affected by the length of cutting at planting and harvested eight months after planting.

LENGTH OF CUTTING	ROOT YIELD (t/ha)	BRANCH (#/plant)	HARVEST Index
Whole stem (ca 1m)	17.8c	3.7a	0.30b
Half of whole stem (ca 0.5m)	21.7b	2.6b	0.37b
Normal length (25cm)	34.8a	1.4c	0.50a

Within columns means with common letters are not significantly different (LSD, 5% level)

SOURCE: Apilar and Villamayor, 1981

Table 9. Effect of length of stem cutting on cassava yield

LENGTH OF CUTTING (cm)	ROOTS (No./plant)	WEIGHT (g/root)
10	4.35	269
25	5.93	333

SOURCE: Villanueva, 1985

Table 10. Stem diameter, germination and yield of cassava (cv. Golden Yellow) produced at different population densities and harvested 6.5 months after planting[1/]

POPULATION (PLANTS/Ha)	STEM DIAMETER (Cm)	SPROUTING (%)	YIELD (T/Ha)
13,333	1,66a	99a	24.4a
17,777	1,42b	92a	24.1a
26,666	1,36b	90a	24.8a
53,333	1,06c	97a	24,3a

1/ Within columns, means with common letters are not significantly different (HSD, 5%level)

SOURCE: Villamayor, 1982

Table 11. Effect of storage duration on growth and yield of cassava with cutting treated with fungicides before storage and kept under a bamboo canopy.[1/]

STORAGE DURATION (DAYS)	SPROUTING (%)	WEIGHT OF TOPS (T/HA)	ROOT YIELD (T/HA)
0	100a	33a	25b
60	100a	32ab	30a
120	100a	30b	24b
180	98b	29b	27ab

1/ Means followed by the same letters are not significantly different (DMRT, 5% level)

SOURCE: CIAT, 1980

Table 12. Three pesticide mixtures for stake treatment before storage or planting.

TRADE NAME	COMMON NAME	RATE (AMOUNT OF COMMERCIAL PROD PER LITER OF WA
Formula No. 1		
Dithane M-22	maneb	2.22 g
Antracol	propineb	1.25 g
Vitigran 35%	copper oxychloride	2.00 g
Malathion W.P. 4%	malathion	5.00 g
Formula No. 2		
Malathion E.C. 57%	malathion E.C.	1.5 cc
Bavistin W.P. 50%	carbendazim	6.0 g
Orthocide W.P. 50%	captan	6.0 g
Formula No. 3		
Orthocide W.P. 50%	captan	6.0 g
Bavistin W.P. 50%	carbendazim	6.0 g
Aldrin 2.5%	aldrin	1.0 g/stak

SOURCE: Cock, 1985 b

Table 13. Effect of planting time on yield of cassava.

PLANTING DATE	YIELD (T/HA)
May	39
June	40
July	36
August	31
September	27
October	22

SOURCE: Villanueva, 1985

Table 14. Effect of planting depth on cassava yield.

PLANTING DEPTH (CM)	YIELD (T/HA)
5	29.71
10	29.26
15	28.17

SOURCE: Villanueva, 1985

Table 15. Effect of spacing on cassava yield.

SPACING (CM X CM)	PLANTS/HA	YIELD (T/HA)
60 x 69	27,777	26.63
60 x 100	16,666	29.39
80 x 100	12,500	28.12
100 x 100	10,000	29.42
120 x 120	6,944	25.55

SOURCE: Villanueva, 1985

Table 16. Root yield of cassava (cv. Golden Yellow) at different plant population densities averaged across time of harvest.1/

POPULATION (PLTS/HA)	SPACING BETWEEN HILLS2/ (CM)	MARKETABLE YIELD (T/HA)	TOTAL YIELD (T/HA)
13,333	10.0	24.1	29.0
15,000	66.6	23.5	29.4
20,000	50.0	20.9	27.4
25,000	40.0	19.1	28.3

1/ No significant differences among the treatments

2/ Distance between rows is 75 cm

SOURCE: Villamayor and Destrisa,1982

Table 17. Effect of spacing on root and stem (25 cm) yields of cassava.

PLANTING SPACE (CM X CM)	NUMBER OF (PLANTS/HA)	ROOT YIELD (T/HA)	STEM YIELD (CUTTINGS)
100 x 75	13,333	25	113,000
25 x 75	53,333	15	322,000

SOURCE: Villamayor, 1981

Table 18. Effect of time and duration of weed control on cassava (cv. Golden Yellow) yield.

TREATMENT	YIELD (T/HA)
Handweeded (HW) for 2 weeks from planting (WFP)	17.64
HW for 4 WFP	20.56
HW for 6 WFP	27.93
HW for 8 WFP	30.18
Handweeded control	29.60
HW from 2 WFP until 100% cover	27.24
HW from 4 WFP until 100% cover	24.62
HW from 6 WFP until 100% cover	18.62
HW from 8 WFP until 100% cover	18.83
Unweeded control	10.15

SOURCE: Decusmo, 1978

Table 19. Yield and income under different cultivation/weed control treatments in cassava (cv. Golden Yellow) and harvested 6.5 months after planting.

TREATMENT 1/	YIELD (T/HA) 2/	NET RETURN (₱)	ROI 3/
OB 2WAP plus HWWR and HU 4 WAP	24.0ab	5840	2.27
OB 2 WAP plus HU 4 and 6 WAP	22.0b	5490	2.36
OB 2WAP + HWWR 3WAP + HU 5 and 7 WAP	30.3a	8210	3.02

1/ OB - off-barring; WAP - weeks after planting; HU - hilling-up; HWWR - hand weeding within row

2/ Means followed by common letters are not significantly different (LSD, 5%)

3/ Return on investment

SOURCE: Villamayor and Keoma, 1983

Table 20. Root number and weight of cassava roots (cv. Golden Yellow) under moisture stress (155 mm of rain in 5 months).

TREATMENT	ROOT NO./PLANT	ROOT WT. (KG/PLANT)
Control (rain dependent)	12.7 b	2.4 b
Watered 3.5, 4.5 and 5.2 months after planting	16.5 a	3.4 a

1/ Within columns means followed by a common letter are not significantly different (LSD, 5%)

SOURCE: Villamayor and Destriza, 1985.

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Table 21. Root yield (t/ha) of cassava (cv. Golden Yellow) eight months after planting as affected by fertilization level based on soil analysis of four locations.

FERTILIZATION APPLICATION	LOCATION			
	MAGANHAN	MAHAYAG	IGANG	KABALASAN
Control (no fertilizer)	9.0	3.4	20.8	4.9
1/2 Recommended level	18.3	16.3	21.7	14.0
Full fertilizer recommendation	20.0	18.8	26.8	15.5

SOURCE: Villamayor, unpublished data

Table 22. Effect of continuous cropping on yield of cassava.

CROPPING SEQUENCE	YIELD (T/HA)
First	40.6
Second	37.5
Third	25.6

SOURCE: Villanueva, 1985

Table 23. Nutrients Extracted by Various Crops per Ton of Dry Matter Harvested

CROPS	NUTRIENTS N	P	K	TOTAL
Cassava (roots)	6	1	11	18
Potatoes (tubers)	17	3	26	46
Maize (grain)	19	3	4	26
Rice (grain)	16	3	3	22
Beans (grain)	37	3	22	62

SOURCE: Howeler, 1985

Table 24. Critical Levels of Soil Parameters for Cassava

PARAMETER	CRITICAL LEVEL	METHOD OF ANALYSIS*
pH	4.6 - 7.8	1:1 Soil-water ratio
Al (me/100 g)	2.5	1N K Cl
Al -sat (%)	80	Al/(Al + Ca + Mg +K)
P (ppm)	7 - 8	Bray I
	6 - 10	Bray II
	8	Olsen - EDTA
	9	North Carolina
K (me/100 g)	0.09 - 0.15	NH4 - acetate
	0.17	Bray 11
	0.15	North Carolina
Ca (me/100 g)	0.25	NH4 - acetate
Conductivity (mmhos/cm)	0.5 - 0.7	Saturation extract
Na - saturation (%)	2.5	NH4 - acetate
Zn (ppm)	1.0	North Carolina
Mn (ppm)	5 - 9	North Carolina

*Bray I = 0.025 N HCl + 0.03 N NH4F
Bray II = 0.1 N HCl + 0.03 N NH4F
Olsen -EDTA = 0.5 N NaHCO3 + 0.01 M Na-EDTA
North Carolina = 0.05 N HCl + 0.025 N H_2SO_4
NH4-acetate = 1 N NH4 - acetate at pH 7

SOURCE: Howeler, November 1985

Table 25. Nutrient Concentration in Youngest Fully-Expanded Leaf Blades of 3-4 months old cassava, corresponding to Various Nutrient Status of the Plant

ELEMENT	NUTRIENT STATUS				
	DEFICIENT	LOW	SUFFICIENT	HIGH	TOXIC
N (%)	< 4.7	4.7 - 5.1	5.1 - 5.8	> 5.8	-
P (%)	< 0.30	0.30- 0.36	0.36- 0.50	> 0.50	-
K (%)	< 1.0	1.0 - 1.3	1.3 - 2.0	> 2.00	-
Ca (%)	< 0.65	0.65- 0.75	0.75- 0.85	> 0.85	-
Mg (%)	< 0.27	0.27- 0.29	0.29- 0.31	> 0.31	-
S (%)	< 0.24	0.24- 0.26	0.26- 0.30	> 0.30	-
B (ppm)	< 20	20- 30	30- 60	60-100	> 100
Cu (ppm)	< 5	5 - 6	6 - 10	10 - 15	> 15
Fe (ppm)	< 100	100 - 120	120 - 140	140 - 200	> 200
Mn (ppm)	< 45	45 - 50	50 - 120	120 - 250	> 250
Zn (ppm)	< 25	25 - 30	30 - 60	60 - 120	> 120

SOURCE: Howeler, 1985

Legend:
- Deficient = 60% max yield
- Low = 80 - 90% max yield
- Sufficient = 90 - 100% max yield
- High = 100 - 90% max yield
- Toxic = 90% max yield

Table 26. Yield of cassava at different ages of harvest.

HARVEST AGE (MONTHS)	YIELD (T/HA)
8	16.18
10	23.51
12	31.33
14	37.56
16	41.53
18	45.25

SOURCE: Villanueva, 1985

AGROTECHNOLOGY TRANSFER BASED ON SOIL TAXONOMY[1/]
The Benchmark Soils Project Experience

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GENERAL

Uehara (1981) defined agrotechnology transfer as the taking of an agricultural innovation from its site of origin to a new location where it is likely to succeed. Transfer of both the mechanical and biological components of agricultural technology can occur through (i) material transfer and (ii) knowledge transfer. While material transfer, such as seed or machinery, are rather straightforward, knolwedge transfers are much more complex and difficult as they involve the conveyance of scientific information about how to employ inputs, such as germplasm, fertilizer, tillage implements, or irrigatio water, to produce optimal yields (Beinroth et al., 1980). For agrotechnology transfer to succeed, the transferred technology must be compatible with the characteristics of the farmer's land and with the labor, capital and management resources of the farmer. Agrotechnology appropriate for transfer to a specific should thus be (1) technically sound, (2) environmentally safe, (3) economically feasible, (4) sociall desirable, and (5) culturally acceptable.

One way of transferring agricultural knowledge and experience is by analogy. In this approach soil and climate classifications are used to identify analogous areas. The assumptions are (i) that the tax. of the classifications stratify the environment with sufficient precision to allow successful transfers, and (ii) that all occurrences of a defined class have similar production potentials and responses to management. While general, multi-attribute schemes of agroclimatic classification are of limited value in the analogue transfer of technology (Burgos, 1968), soil classifications have been more successful. The U.S. system, Soil Taxonomy (Soil Survey Staff, 1975), is particularly suited for this purpose as it incorporates both soil and climate and thus stratifies the agro-environment into distinct niches of agroproduction (Beinroth, 1984).

Transfer by analogy is also implied in the concept of benchmark soils advanced by C.E. Kellogg (1961). As currently defined, a benchmar soil is an important soil selected for intensive study and complete

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[1/] Lecture for the XIV International Forum on Soil Taxonomy and Agrotechnology Transfer, Philippines, March 3-20, 1986.

characterization because it occupies a key interpretative position in the classification and/or covers large areas (Miller and Nicholas, 1980). A benchmark soil represents a reference site from which research results can be extrapolated to other areas with similar characteristics.

Soil scientists have long assumed that soil classification, in conjunction with soil surveys, provides an adequate basis for the transfer of pedologic knowledge and agronomic experience. Many authoritative statements can be found in the literature which allude to this conjecture. In the foreword to the FAO-Unesco Soil Map of the world (FAO, 1974), for example, it is stated that one of the objectives of the map is "to supply a scientific basis for the transfer of experience between areas with similar environments... (because)... with the tremendous amount of knowledge and experience gained in the management and development of different soils throughout the world, the hardship perpetuated in some areas by methods of trial and error is no longer justified". And G.D. Smith (1965) pointed out that "We make the basic assumption that experience with a particular kind of soil in one place can be applied to that particular kind of soil wherever it exists if consideration is taken of any climatic differences".

The stated assumptions and the transfer hypothesis implied therein were subjected to a thorough scientific test in the Benchmark Soils Project of the Universities of Hawaii and Puerto Rico whose primary objective was to test the transferability of agroproduction technology on the basis of soil families as defined in Soil Taxonomy.

THE BENCHMARK SOILS PROJECT

The Benchmark Soils Project (BSP) was established in 1974 to demonstrate the viability of a soil classification based approach to the transfer of agroproduction technology in the tropics as a means to increase the efficiency of agronomic research through its wide geographical diffusion and thus to accelerate the pace of agricultural development in the developing countries.

In the first comprehensive study of its kind, the Benchmark Soils Project ventured to scientifically establish the transferability of agrotechnology, particularly soil and crop management experience. Central to this effort is the benchmark soils family as defined in the US system of soil classification, Soil Taxonomy. The intent of the soil family is to group together soils that are relatively homogeneous in properties important to plant growth. Consequently, comparable phases of all soils of a family should have a common and predictable response to management practices, correlative input-output characteristics, and similar crop production potential. The transfer hypothesis underlying the

BSP is derived from these principles and is that empirical agroproduction experience gained with a soil of a particular family can be transferred and extrapolated to all other comparable members of that family, irrespective of their geographic occurrence.

The general aim of the project was to experimentally and statistically validate this hypothesis. The primary research objectives were:

1. To demonstrate that soil management and crop production knowledge can be transferred among tropical countries on the basis of soil families as defined in Soil Taxonomy; and
2. To establish that the behavior of tropical soils and their potential for food production under various levels of management inputs can be predicted from soil taxonomic units.

The basic research strategy of the project was to conduct a series of identical experiments in a network of soils belonging to the same family, monitor crop performance and weather conditions, and statistically compare response to management and yields. The experiments were highly controlled, drip-irrigated fertility trials with phosphorus and nitrogen as variables and maize as the test crop. They were specifically designed to generate the data base for the statistical analyses. A total of 157 of these so-called transfer experiments were conducted as well as 63 pragmatic soil and crop management experiments and variety trials.

Three contrastingly different soil families representing three distinct agroclimatic zones of the tropics were chosen for experimentation: the clayey, kaolinitic, isohyperthermic Tropeptic Eutrustox, the thixotropic, isothermic Hydric Dystrandepts, and the clayey, kaolinitic, isophyperthermic Typic Paleudults.

The project established a research network that comprized 23 experiment sites in Brazil, Cameroon, Hawaii, Indonesia, the Philippines, and Puerto Rico. Collaborating with the project were the Empresa de Pesquisa Agropecuaria de Minas Gerais (EPAMIG) in Brazil, the General Delegation of Scientific and Technical Research (DGRST) in Cameroon, the Philippine Council for Agriculture and Resources Research and Development (PCARRD) in the Philippines, and the Soil Research Institute (SRI) in Indonesia.

The field data of the transfer experiments were statistically evaluated with three different techniques developed under the auspices of the BSF. They were the P-statistic, the confidence interval procedure, and a graphical method (Benchmark Soils Project, 1982a, Cady et al., 1982) The results with the confidence interval procedure and the graphical method provided strong positive evidence for transferability. The results with the P-statistic were less conclusive but not negative. The graphical method was particularly illustrative as it allowed an instant visual appraisal of the transferability of management practices. The comparison of predicted and observed response surfaces showed that, if certain site variables are considered, fertilizer response at a new site can be predicted on the basis of experiment conducted at other sites with the same soil family essentially as well as by an experiment conducted at the new site.

On balance, the statistical studies yielded a qualified validation of the postulated transfer hypothesis and, by implication, of the concepts of benchmark soils and the soil family. In view of the complexity of the conjecture under study and considering the difficulties encountered in its experimental and mathematical corroboration, these results are very reassuring.

Moreover, the agronomic results of the project demonstrate that soil families as defined in Soil Taxonomy indeed provide groupings of soils that have relative homogeneity in properties important to plant growth, common and predictable responses to management practices, and similar crop production potential and thus stratify the agroenvironment into distinct niches of agroproduction. This is evidenced, for example, by the very similar maximum yields obtained in Puerto Rico and Brazil with comparable inputs, the absence of response to potassium at both locations, and the fact that one specific variety of maize performed best in the two countries. Even a casual interfamily comparison of data obtained showed that the three soil families are characterized by distinctly different patterns of soil behavior. The P-isotherms, for instance, which are in large measure conditioned by soil family characteristics, are markedly different for the three soil families but very similar for all soils of the same family.

The highest mean maize yields were about 9,000 kg/ha for the Eutrustox in Puerto Rico and Brazil, 7,000 kg/ha for the Hydrandepts and 6,700 kg/ha for the Paleudults. Although these yields are not vastly different, the fertilizer inputs necessary to achieve them definitely are. Whereas the Eutrustox required only about 40 kg/ha to obtain these yields, the Dystrandepts needed 150 kg/ha and the Paleudults 100 kg/ha. Furthermore, the Dystrandepts and Paleudults required substantial applications of potassium and lime which were not needed for the Eutrustox. The soil management technology developed for Eutrustox is therefore clearly not applicable to either Dystrandepts or

Paleudults, reflecting the soil-specificity of agrotechnology transfer as implied in the transfer hypothesis.

The results of the Benchmark Soils Project (1982a, 1982b) show that transfer of soil management practices can be successfully achieved and yileds can be predicted with considderable accuracy on the basis of Soil Taxonomy families, if additional site factors are taken into account. By implication, this validates the concept of the soil family as postulated in Soil Taxonomy and the principle of benchmark soils. A comparison of the results obtained in soil fertility and management experiments at the various sites of the project network also shows that Soil Taxonomy stratifies the agroenvironment into distinct niches of agroproduction and allows qualitative predictions of soil potential and management requirements. In conjunction with soil surveys, Soil Taxonomy thus defines the geographic and pedologic applicability of agronomic experience.

At the same time, the project results allude to the limitations of analogue transfer of agrotechnology based only on Soil Taxonomy taxa. Soil Taxonomy constitutes an effective vehicle for agrotechnology transfer in cases where a high degree of specificity is not needed, such as in large-scale land use planning. Transfer of agrotechnology to specific farm situations, however, requires a more holistic approach that should be based systems analysis and employ computer simulation techniques to model the soil-weather-crop-management continuum.

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A SYSTEMS-BASED APPROACH TO AGROTECHNOLOGY TRANSFER[1/]

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Transfer of agrotechnology has evolved along an evolutionary path that led from trial and error and statistical methods to transfer by analogy and, more recently, systems analysis and simulation. The disadvantage of transfer by trial and error is that it is attained slolwly and at high social cost. Statistical techniques, mainly analysis of variance and multiple regression, lend themselves more to interpolations than extrapolations. Transfer by analogy has traditionally been advocated by pedologists on the rationale that soil classification stratifies the agroenvironment in sufficient detail to facilitate transference. This assumption has been shown to be valid for instances where the emphasis in on broad assessments rather than specific predictions and prescriptions. Information, however, can only be transferred from the locations where it has been generated, leading to the need for ever more research sites. Simulation models have long been recognized as the conceptually best approach to agrotechnology transfer, but various constraints have prevented their use in the past. Advances in crop modeling, coupled with advances in computer technology, now make that approach entirely feasible.

As crop performance results from the interaction of a multitude of soil, plant, climate and management factors, the development and evaluation of crop simulation models requires data that monitor the whole genotype environment management system. Cultivar-specific "minimum data sets" have, therefore, been devised which identify the soil, atmosphere, plant, and management parameters needed for modeling. Such data sets should be collected at sites that cover the complete spectrum of environmental conditions where the crop will grow, including sites with severe stress. The effective utilization of these data sets require a functional data base management system whose output is compatible with the input requirements of the models.

The biophysical processes of agricultural systems can be described mathematically and hence simulated, but the socio-economic and other judgemental aspects of the system defy such mechanistical treatment and mathematical expression. However, the techniques of knowledge engineering known as expert systems now allow to address these aspects, either in combination with simulation models or independently. In addition, stochastic methodologies are needed to

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deal effectively with the systematic and random variability, both spatial and temporal, that characterizes the soil landscape.

Systems-based agrotechnology transfer thus integrates three main elements: data bases, simulation models and expert systems. The International Benchmark Sites Network for Agrotechnology Transfer (IBSNAT) exemplifies this approach. Central to this project is a relational data base management system and a generic crop simulation model that is user-oriented, of universal applicability, and can be executed on microcomputers with a minimum of input data.

IBSNAT is an outgrowth of the Benchmark Soil Project of the Universities of Hawaii and Puerto Rico. It was implemented in 1982 and is funded, in part, by the U.S. Agency for International Development under a contract with the University of Hawaii. IBSNAT is a collaborative endeavor that consolidates a group of agricultural research centers into a prototype network for the purpose of developing, validating and utilizing a scientific methodology for the effective transfer of agrotechnology among and within countries of the lower latitudes.

IBSNAT's goal is to devise ways and means that will enable countries in the tropics and subtropics lacking resources and institutional capacity to meet their agricultural development needs through technology transfer. Accordingly, the project's objectives are to:

- accelerate the diffusion of agricultural innovations from their sites of origin to new locations,
- increase the success rate of technology transfer to farmers' fields, and
- assess the long-term effect of agricultural practices on the environment.

IBSNAT aims to achieve its objectives by:

- establishing a network of collaborating national, regional, and international agricultural research centers to serve as sources and recipients of agrotechnology;
- identifying the soil, crop, weather and management data needed to successfully transfer agrotechnology,
- testing soil, crop, weather and management simulation models in a network of experimental sites;
- using systems analyses, simulation models and expert systems to **predict** the performance of crops and management systems; and
- training collaborators in the use of systems analysis and simulation and management models for agrotechnology transfer.

The realization that in successful transfer the characteristics and requirements of cultivars must be compatible with the environmental conditions at the transfer site implies that quantitative knowledge of the genotype-environment-management interactions must be generated and incorporated into the crop performance simulation models. In the course of field experimentation it is thus essential to collect balanced sets of soil-crop-weather-management data that monitor the whole system and facilitate the identification of "minimum data sets" which are a prerequisite for transfers via simulation techniques.

The crops for which simulation models are being developed by IBSNAT include four cereals (maize, rice, sorghum, wheat), three grain legumes (beans, groundnuts, soybeans) and three root crops (aroids, cassava, potatoes). Guidelines for the experiment designs and detailed procedures for data collection have been completed and circulated to IBSNAT collaborators. Field research is currently in progress at 30 benchmark sites in 16 developing countries.

The maize and wheat models have been subjected to global testing and were found to predict crop performance with reasonable accuracy. The soybean model is operational and ready for worldwide validation, the seven other models are in various stages of development.

The project has further designed a Data Base Management System for storing and analyzing the data sets collected in the network. The system employs commercially available software (dBase III by Ashton-Tate) and is characterized by ease of use, flexibility, precision, relatability, and data independence. Moreover, the system's outputs are identical to the model inputs, enabling all IBSNAT crop models to access the data from a single data base management system.

IBSNAT is currently developing a computerized Decision Support System for Agrotechnology Transfer (DSSAT) that attempts to provide users with convenient and easy to use procedures for a systematic evaluation of the performance of agrotechnology at new locations. In order to be able to generate the desired outputs, the DSSAT incorporates and links the crop models, data files, the data base management system, utility programs, and, eventually, expert systems.

Finally, IBSNAT fosters the development of networks that employ a system-based approach to the transfer of agrotechnology in a regional context. The project therefore assisted scientists from ASEAN countries in developing the proposal for an ASEAN Benchmark Sites Network for Agrotechnology Transfer (ABSNAT). The project proposal has recently been approved by ASEAN's research body and is now being considered for funding.

SOIL SUITABILITY AND MANAGEMENT IMPLICATIONS OF SOIL TAXONOMY WITH SPECIAL REFERENCE TO TREE CROP CULTIVATION[1/]

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INTRODUCTION

The logic of soil classification has been summarized by Cline (1949). He states that the purpose of any classification is to organize our knowledge into groups so that the properties of the objects classific may be easily remembered and the relationships between members of groups and between members within a group are readily understood. Cline also stated that any classification must have specific objectives. Thus any proposed system of soil classification should satisfy these objectives.

In many countries particularly, the developing countries of the Tropics, soil classification and soil surveys have and are being carried out with the objective of interpreting the results of these soil surveys for agricultural use. Data from soil surveys is vital for crop selection and for the management of the soils so that maximum benefits can be obtained. Increasingly more countries are using Soil Taxonomy as a basis for carrying out soil surveys and interpreting the resultant soil maps. The reason for this is obvious when one looks at the title of the book: -

SOIL TAXONOMY
A Basic System of Soil Classification for Making and
Interpreting Soil Surveys

The objectives of this paper is to examine the interpretations that can be made using, Soil Taxonomy, for the suitability and management of perennial crops. The importance of Soil Taxonomy as a means of technology transfer for perennial crops will also be briefly discussed.

CATEGORIES OF CLASSIFICATION

Six categories have been recognized in Soil Taxonomy. viz: Order, Suborder, Great Group, Subgroup, Family and Series. These categories serve specific purposes and the amount of detail that goes into each definition increases in the lower categories. In addition, since Soil Taxonomy is an hierarchical system, any property or criteria used at a higher level is also implied at the lower levels. The general criteria used at each categorical level is summarized below.

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Orders

The orders are differentiated by the presence or absenc of diagnostic horizons or features. These are indicators of differences in the degree and kinds of dominant sets of soil-forming processes that have helped to form the soil. Ten orde are described in Soil Taxonomy - Alfisols, Aridisols, Entisols Histosols, Inceptisols, Mollisols, Oxisols, Spodoscls, Ultiso and Vertisols.

Suborders

The suborders generally are defined on the basis of properties that affect the current processes of soil development. In most suborders, soil moisture and temperature regime are the properties used. In the case of organic soils · Histosols, the degree of decomposition of the organic soil material is used.

Great Groups

In this category, a number of soil properties are used. The whole soil is characterized including the assemblage of horizons and the most significant property of the whole soil as determined from the number and importance of accessory properties. Although the differentiating properties of the great group are few, there are many accessory properties.

Subgroups

The categories above the subgroup focus on the indicatio of causes of sets of processes that appear to dominate the cour or degree of development. However, many soils have in addition to these, properties that ae subordinate but yet important mark of soil-forming processes.

Within a given great group, the soil may show subordinate indicators of processes that are dominant in other orders, suborders or great groups but in the given great group these processes serve only to modify other more important and dominant processes. Identifying these less significant processes at the subgroup level helps to show the relationship to other kinds of soils.

Families

In this category, the intent has been to group the soils within a subgroup that have similar physical and chemical properties affecting their response to use and management in particular to agriculture.

Series

The soil series is the lowest category. Differentiating characteristics of a series cannot fall outside the limits established for the family.

SOIL SUITABILITY AND MANAGEMENT INTERPRETATIONS

General Principles

The determination of the suitability of a piece of land for a specific agricultural use and the type of management is one of the more important uses of soil map (Paramananthan and Law, 1980). Before examining how the Soil Taxonomy can be used for this purpose it may be pertinent to examine briefly the general principles of such interpretations.

Experience and research of crops grown on a variety of soils forms the basis of such interpretations. This experience may come from many sources including experimental and farmer experience. The lack of a common basis for comparing soils between different countries has for a long time limited the use of such data to within a country. However, with the wider use of Soil Taxonomy the data base used has become international.

Research and experience of a variety of crops grown on a variety of soils makes it feasible to develop tables showing the limitations to crop growth. Initially these tables only considered soil characteristics (Wong, 1974). Today, however, other criteria such as climate is also included (Bunting, 1981). The limitations to crop growth are rated as being minor, moderate, serious or very serious for the growth of a particular crop. The degree of severity being based on estimated decline in yield due to that characteristic.

From the results of the soil survey a table showing the physical and chemical characteristics of the soil can also be developed. In evaluating a piece of land for the suitability for a particular land use one has just to compare the table of limitations to crop growth with that of the soil properties. By this comparison the land can be evaluated for that particular land use. In the simplest method of evaluation the soil mapping unit is given the worst rating it receives as an overall land suitability rating. However, some limitations such as drainage class, presence of acid sulfate horizon may be overcome by various management practices. Hence, it is possible to identify various management practices that can be used to overcome a particular limitation thereby upgrade the soil.

Crop Growth Limitations

Depending on the crop a variety of factors can affect crop growth. In general however, these limitations can be sub-divided into five main groups: -

i. Climatic Characteristics
ii. Topography
iii. Wetness
iv. Physical Soil Conditions
v. Soil Fertility Conditions

Each of these five groups can be further sub-divided into different land characteristics depending on how these factors will influence the growth, yield and management of that particular crop. The class limits or degree of limitation for each characteristic will vary according to how that characteristic affects the particular crop.

Based on the author's experiences with the growth of oil palm, cocoa and rubber on a variety of soils, tables 1, 2, 3 and 4 have been developed for use in Malaysia. Each of these five groups of characteristics is further sub-divided into a number of characteristics. The number of characteristics used is largely dependent on how these characteristics affect the growth and management of the crop. The list of characteristics used is not exhaustive and can be increased or decreased based on new data from research. The class limits for the degree of limitations are more difficult to establish but are established on the basis of research findings and experience.

Use of Soil Taxonomy in the Evaluation Process

As mentioned earlier, the criteria used at the family category in Soil Taxonomy have been selected in such a way as to make agricultural interpretations. However, depending on the land characteristic concerned they are used at various levels.

a. Climatic Characteristics

The climatic characteristics used in the land evaluation process include the presence/absence of a dry season and the mean annual temperature. Both of these characteristics are used in Soil Taxonomy.

The soil moisture regime is often used at the Sub-order level in Soil Taxonomy. Soils having an ustic moisture regime for example as the ustults are not suitable for both oil palm, and cocoa while they are marginal for rubber. The soil temperature regime is used at the family level and only those soils having an isohyperthermic temperature regime are well suited for the three crops concerned. Those with isothermic and isomesic temperatures are not suited for these crops.

From tables 1-3 it appears that both cocoa and oil palm are more sensitive to moisture stress compared to rubber and hence yields of oil palm and cocoa will be seriously affected by moisture stress. From these considerations one can interpret that oil palm and cocoa grown on the well drained soils with an oxic horizon especially those having red colours and well aggregated structures would be seriously affected by yield fluctuation. Hence, rubber is preferred on such soils (Paramananthan and Eswaran, 1984). It is for this reason that the northern part of Peninsular Malaysia is considered to be not suitable for both cocoa and oil palm as the climate there is marginal to ustic.

b. Topography

Topography or slope is often mapped at the phase level on a soil map. The different systems of harvesting employed for the three crops considered, makes slope an important consideration. Slopes also affect the erodability of the soil. This criteria is not readily inferred from the classification of the soil using Soil Taxonomy.

c. Wetness

The wetness characteristic is divided into drainage and flooding. The drainage class of a soil can be inferred from the classification of the soil. Soils which are poorly drained often have mottles with a low chroma and have an aquic moisture regime. Hence soils that belong to the Aquepts and Aquults have an aquic moisture regime. Soils that have colours with a low chroma lower down in the subsoil are imperfectly drained and this is indicated by the sub-group in the classification e.g. Aquic Tropudult. Oil palm tolerates poorly drained conditions while rubber does not. Cocoa on the other hand can grow well on poorly drained soils if the water-table is kept below 75 cm. Thus, many coastal areas which have been drained artificially have soils of the order Aquepts. Such soils can be planted with oil palm and cocoa but are considered to be unsuitable to marginal for rubber. On the other hand the imperfectly drained soils (aquic subgroups) can support all the three crops. With the improvement in drainage, the Paleudults, Haplorthox and Dystropepts the performance of rubber improves.

d. Physical soil conditions

A number of soil characteristics can be evaluated under this category. The texture or particle-size class when gravels are present is an obvious characteristic that can be used. In Soil Taxonomy, the particle size class is used at the family level and hence this interpretation can be readily made. In order to accommodate textural variations with depth and the presence of stonelines the characteristic is evaluated using a weighted average to 100 cm. Where gravel layers are present a further downgrading is used. Within one textural class e.g. clay and soil may have fine structures and friable consistence as in Oxisols or be coarse-structured and compact as in some Tropudults. This difference can often be inferred from some accessory properties. Oxisols generally tend to be fine-structured and friable thereby making root penetration and workability relatively easy.

The presence of rock or other substratum will severely inhibit root growth. In Soil Taxonomy the lithic, paralithic and petroferric contact reflect these conditions. These criteria are used at the subgroup level. Similarly the presence of a sulfuric horizon at various depths in the soil will determine its suitability and management. A sulfuric horizon which occurs within 50 cm of the soil surface will key the soil out at great group level as a Sulfaquept. If the sulfuric horizon occurs below 50 cm depth then it is indicated at the subgroup level as a Sulfic Tropaquept. The utilization and management of these acid sulfate soils is strongly related to the depth of this acid sulfate layer (Paramananthan and Eswaran, 1984). The knowledge of the depth of the sulfuric horizon is vital to determine the type of water control and management that has to be used if these soils are to be successfully used for agriculture.

e. Soil fertility conditions

The low fertility of tropical soils has long been considered to be the cause of low yields. The mineralogy and organic matter content of the soil reflect the fertility status of the soil. The mineralogy of the soil is reflected in the mineralogy class at family level. Soils belong to the kaolinitic or oxidic class are obviously less fertile than those of the mixed mineralogy class. Soils of the oxidic family may also present problems of phosphate fixation. The low fertility of tropical soils is often reflected in their low effective cation exchange capacity. Thus, soils with an oxic horizon have an effective CEC of less than 16 while soils belonging to the oxic or orthoxic subgroup have an effective CEC of less than 24. This low CEC implies that if high yields are to be obtained and maintained a good manurial program is essential.

The adaptability of the difrerent perennial crops to such low fertility conditions varies. Rubber is somewhat more tolerant of such soils while cocoa is least tolerant. In Oxisols, often the calcium and magnesium levels are low a factor which is critical for cocoa. On the other hand, fertile soils developed over marine clays with smectitic mineralogy have high values for these two elements. This high level of magnesium can cause coagulation of latex in rubber and hence reduce yields.

In many Oxisols, the only source of nutrients is the organic matter content of these soils is reflected in the colour of the surface horizons. Thus, the darker coloured umbric epipedons are probably more fertile than the light coloured ochric epipedons. The base saturation which is also used as a soil fertility characteristic is used both at the order level viz Alfisols and Ultisols and at the great group level viz Dystropepts and Eutropepts.

MANAGEMENT IMPLICATIONS

The differing soil and climatic requirements of the tree crops considered played a dominant role in the crop diversification program. In the pre-1950 years rubber was planted on both poorly drained Aquepts and well drained Oxisols. However, once soil survey and crop performance data were available rubber was moved to the Great Groups of Paleudult, Tropudult, Acrorthox and Haplorthox. Oil palm on the other hand was increased on the Tropaquepts and Sulfaquepts. Cocoa requiring more fertile soils was planted on the Tropaquepts, Tropudults and Eutrorthox. The extent of coconut in Malaysia has been reduced somewhat being now confined to the Tropaquepts and Sulfaquepts.

The relationship between crop performance and soil units have been studied by many workers and summarized by Ng (1983). This is reproduced as Table 5. From this table it is obvious why oil palm or cocoa/ coconut is preferred to rubber on Aquepts.

The increasing interaction between the use of soil survey data and cultivation practice and fertilizer use has resulted in the identification of the nutrient inputs required for a particular crop on a specific soil unit. This information has been complied by Ng (1983) and is given in Table 6. From this table it can be seen that priorities of nutrient inputs vary with soil characters as well as crops. Thus, in the case of oil palm, the lower demand for nutrients are apparent in most of the Aquepts while higher nutrient requirements including copper and boron are needed on the Psamments and Fibrists. For cocoa, calcium is a necessity but not for rubber.

POTENTIAL FOR AGROTECHNOLOGY TRANSFER

In the past large amounts of money, time and energy have been wasted by duplicating research in many countries. This was because no common system of soil classification was used. However, with the introduction and use of Soil Taxonomy a common basic language of communication has been developed. The Soil Taxonomy has enabled us to compare soils in different countries and assist in the transposing of research findings from one country to another.

If a Malaysian soil scientist says that the Rengam Series is well suited for rubber, oil palm and cocoa it does not mean very much to other soil scientists who are not familiar with the soil. However, if he says in addition that the Rengam Series is a clayey, kaolinitic isohyperthermic, Typic Paleudult developed over granite, then the soil scientist in Thailand can equate this soil with the Phuket Series in their country. The reserach findings on the Malaysian soil could then be used in Thailand as a basis for further research without the need to repeat any basic experiments already carried out in Malaysia. This transfer of technology is much easier **with perennial crops as these crops** are less demanding. Annual crops depend largely on topsoil characteristics which are more stable are used in the evaluation of soils for perennial crops.

CONCLUSION

The soil family in Soil Taxonomy has been defined to assist in making interpretations for agriculture. The classification of a soil to the family level is a summary of both land and soil characteristics which can assist in the land evaluation and management. It is apparent that many of the criteria used in Soil Taxonomy can be used to interpret for evaluating these soils for perennial crops. By matching our experience of crops grown on a variety of soils the necessary interpretations on suitability is feasible.

Soil Taxonomy also assists research workers by providing a means of communication with one another. This has made the need to repeat many experiments obsolete and transfer of technology between countries a reality.

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ɔle 1. Evaluation of Land Characteristics for Oil Palm

CHARACTERISTIC	DEGREE OF LIMITATION NOT LIMITING S1	MINOR S2	MODERATE S3	SERIOUS N1	VERY SER. N2
IMATE					
Annual rainfall (mm)	+ 2,000	1,700-2,0	1,450-1,700	1,250-1,450	- 1,
Dry season (months)	-	- 1	1-2	2-3	3
Mean annual max temp (°C)	+ 29	27-29	24-27	22-24	-
Mean annual min temp (°C)	+ 20	18-20	16-18	14-16	-
Mean annual temp (°C)	+ 25	22-25	20-22	18-20	-
POGRAPHY					
Slope (%)	0-4	4-12	12-23	23-30	+
TNESS					
Drainage	Moderate to imperfect	Well and somewhat excessive	Poor (aeric) (easily drained)	Poor (typic) difficult to drain	Very poo
Flooding	Not flooded	Not flooded	Minor	Moderate	Severe
YSICAL SOIL CONDITIONS					
Texture/structure	Cs, SC, CL, SiCs, SiCL	Co, L, SCo	SCL	SL, LSf	LSco, S
Depth (cm)	100 +	75-100	50-75	25-50	- 25
Depth to top of sulfuric horizon	100 +	75-100	50-75	25-50	- 25
IL FERTILITY CONDITIONS					
Weathering stage (Effective CEC)	+ 16	- 16	-	-	-
Base saturation (%) A horizon	+ 35	20 - 35	- 20	-	-
Organic carbon (%) A horizon	+ 1.5	- 1.5	-	-	-
Salinity millimhos (50 cm)	0 - 1	1 - 2	2 - 3	3 - 4	4 +

NOTES ON EVALUATION FOR OIL PALM

1. Dry season

A month is considered to be "dry" if the total rainfall for the month is less than 100 mm.

2. Texture/Structure

In evaluating the texture, the weighted average of the texture to a depth of 100 cm is used. The weighted texture is evaluated as follows:

Rating for 0-25 cm x 1.75
25-50 cm x 1.25
50-75 cm x 0.75
75-100 cm x 0.25

Where surface or sub-surface gravel layers occur the textural rating is downgraded by a factor as shown below depending on the nature of the gravel.

% GRAVELS \ NATURE	QUARTZ	LATERITE	IRON COATED
3 - 15	75	90	95
15 - 35	60	75	80
35 - 70	50	60	70

A gravel layer of more than 70% is treated as a sub-stratum.

3. <u>Soil Depth</u>

Depth here refers to a substratum or rock i.e. a root restricting layer.

able 2. Evaluation of Land Characteristics for Cocoa

CHARACTERISTIC	DEGREE OF LIMITATION				
	NOT LIMITING S1	MINOR S2	MODERATE S3	SERIOUS N1	VERY SERIO N2
LIMATE					
Annual rainfall (mm)	1,600-2,000	1,400-1,600	1,200-1,400	-1,200	-
	-	2,000-2,500	2,500-3,500	+4,500	+4,50
Length of dry season (months)	-1	1-2	2-3	3-4	+4
Mean annual max temp (°C)	-28	28-30	+30	-	-
Mean annual min temp (°C)	+20	15-20	13-15	10-13	-10
Relative humidity (month with	45-60	40-44	35-39	30-34	-30
lowest value)	-	56-60	61-65	66-75	+75
OPOGRAPHY					
Slope (%)	0-4	4-12	12-23	23-38	+38
INESS					
Drainage	Well to moderate	Somewhat excessive imperfect	Somewhat poor	Poor	Very poor
Flooding	Not flooded	-	-	Minor	Mod -Severe
YSICAL SOIL CONDITIONS					
Texture/Structure	Cs, SC, CL SiCs, SiCL	Co, L, SCo	SCL	SL, LSf	LSco, S
Depth (cm)	100+	75-100	50-75	25-50	-25
Depth to Acid Sulfate Layer	100+	-	75-100	50-75	-50
EMICAL SOIL CONDITIONS					
Weathering stage (Effective CEC)	+24	16-24	-16	-	-
Base saturation (% A horizon)	+50	35-50	20-35	-20	-
Organic carbon (% A horizon)	-1.5	1.5-2.4	2.5-5.0	+5.0	-
Organic carbon (% B horizon)	-1.5	-	1.5-3.0	3.0+	-
Salinity (m mhos)	0-0.5	0.5-1	1-1.5	1.5-2	+2

Table 3. Evaluation of Land Characteristics for Rubber.

CHARACTERISTIC	DEGREE OF LIMITATION NOT LIMITING S1	MINOR S2	MODERATE S3	SERIOUS N1	VERY SER N2
CLIMATE					
Annual rainfall (mm)	+2,000	1,700-2,000	1,450-1,700	1,250-1,450	-1,250
Loss of tapping days (months)	-1	1-2	2-4	+4	-
Dry season (months)	-1	1-2	2-3	3-4	+4
Mean annual max temp (°C)	+29	27-29	24-27	22-24	-22
Mean annual min temp (°C)	+20	18-20	16-18	14-16	-14
Mean annual temp (°C)	+25	22-25	20-22	18-20	-18
TOPOGRAPHY					
Slope (%)	0-12	12-23	23-38	38-48	+48
WETNESS					
Drainage	Good	Moderate	Imperfect	Imperfect and High W.T.	Poor
Flooding	Not flooded	-	-	Minor	Mod-Seve
PHYSICAL SOIL CONDITIONS					
Texture/Structure*	CL, Co, SC, Cs	SiCs, SCL, L	SL, LS(f)	LS(co), Sf, Cm, SiCm	Sco
Depth (cm)	+150	100-150	50-100	25-50	-25
SOIL FERTILITY CONDITIONS					
Weathering stage (Effective CEC)	+16	-16	-	-	-
Base saturation (%) A horizon	+35	-35	-	-	-
Ortanic carbon (%) A horizon	+1.5	-1.5	-	-	-

*Downgrading for Gravel Layers

NOTES ON EVALUATION FOR RUBBER

(1) Loss of tapping days

Any month having a precipitation of more than 500 mm/month is considered to be a "rainy month" and any month with a precipitation of 300-500 mm/month is taken as half a rainy month.

(2) Dry Season

A month is considered to be "dry" if the total rainfall for that month is less than 100 mm.

(3) Texture/Structure

In evaluating the texture the weighted average of the texture to a depth of 150 cm is used. The weighted texture is evaluated as follows.

Rating for	0-25 cm x 2.0	75-100 cm x 0.75
	25-50 cm x 1.5	100-125 cm x 0.50
	50-75 cm x 1.0	125-150 cm x 0.25

Where surface or sub-surface stoniness occurs the textural rating is downgraded by the factor shown for gravel layers

% OF GRAVELS	Q	L	C
3-15%	75	90	95
15-35%	60	75	80
35-70%	50	60	70

A gravel layer of more than 70% is treated as a substratum.

(4) Soil Depth

Depth here refers to the presence of a substratum, rock or other root restricting layer such as acid sulfate layer.

Table 4. Evaluation of Land Characteristics for Coconut

CHARACTERISTIC	DEGREE OF LIMITATION NOT LIMITING S1	MINOR S2	MODERATE S3	SERIOUS N1	VERY SERIOUS N2
CLIMATE					
Annual rainfall (mm)	+2,000	1,600-2,000	1,250-1,600	1,000-1,250	-1,000
Mean annual temperature (°C)	27-32	24-26	22-24	20-22	-20
Length of dry season (months)	-1	1-2	2-3	3-4	+4
TOPOGRAPHY					
Slope (%)	0-4	4-12	12-16	16-23	23+
WETNESS					
Drainage	Imperfect, moderately well, well.	Somewhat excessive	Poor	Very poor	-
Flooding	Not flooded	-	Minor	Moderate	Severe
PHYSICAL SOIL CONDITIONS					
Texture and structure	CL, Co, SC, Cs, SCL, L	LS, SlCs	S	Cm, SlCm	-
Depth (cm)	+100	75-100	50-75	25-50	-25
CHEMICAL SOIL CONDITION					
Weathering state (Effective CEC)	-	-	-	-	-
Base saturation (A horizon %)	+35	20-30	-20	-	-
Organic carbon (A horizon %)	+1.5	-1.5	-	-	-
Salinity (m mhos)	0-4	4-8	0-16	16-20	+20

Table 5. Yield Performance on Different Soil Groups (After Ng, 1983):

SOIL GROUP	RUBBER kg/ha/yr.	OIL PALM Tonne/ha/yr.	COCOA kg/ha/yr.	COPRA kg/ha/yr.
Tropaquept	1,300-1,500	25-30	1,000-1,200	1,500-1,800
Sulfaquept	1,200	20-25	700-800	1,000-1,200
Dystropept	1,400-1,700	18-22	600-700	-
Sulfaquent	700	15-20	400-500	600-800
Paleudult	1,500-1,700	20-22	800-900	-
Tropudult	1,400-1,600	20-22	900-1,000	-
Acrothox	1,400-1,800	20-22	900-1,100	-
Haplorthox	1,700	22-25	1,100-1,200	-
Quartzipsamment	800	18-20	500-600	-
Tropaquod	600	-	-	400-500
Tropohumod	700	-	-	500-600
Tropofibrist	600	12-15	<400	-

Table 6. Principal and Subsidiary Nutrient Inputs for Various Tree Crops. (After Ng, 1983).

SOIL GROUP	RUBBER	OIL PALM	COCOA	COCONUT
Tropaquept	N, K	N, K	N, CA, k	N, k
Sulfaquept	P, n, k	P, CA, n, k	CA, P, N	P, ca
Dystropept	P, N	P, N, k, mg	CA, P, N	-
Sulfaquent	P	P, CA, n, k	CA, P, n, k	P, CA, n
Paleudult	N, K, P	N, K, P, mg	CA, N, K, P	N, K, P
Tropudult	N, K, p	N, K, P, mg	CA, N, K, P	N, K, P
Acrothox	N, K, P	N, P, K, mg	CA, P, N, k	-
Haplorthox	N, K, p	N, P, k, mg	CA, P, N, k	-
Quartzipsamment	K, P, N, mg	N, P, K, MG, B	-	-
Tropaquod	-	-	-	K, n
Tropohumod	-	-	-	K, n, p
Tropofibrist	-	CU, K, CA, B	-	K, CA

Note: Capital letter denotes Principal Input
Small letter denotes subsidiary Input.